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L19: Entry 63 of 63 File: USPT Dec 15, 1987

DOCUMENT-IDENTIFIER: US 4712560 A
TITLE: Apparatus and method of acquiring physiological gating signals for magnetic resonance imaging of moving objects

Brief Summary Text (2):
This invention relates to magnetic resonance imaging (MRI) apparatus and, more particularly relates to non-contact techniques for acquiring respiration and cardiac gating waveforms for use in connection with MR imaging.

Brief Summary Text (4):
In the past, the MRI phenomenon has been utilized by structural chemists to study, in vitro, the molecular structure of organic molecules. Typically, MRI spectrometers utilized for this purpose were designed to accommodate relatively small samples of the substance to be studied. More recently, however, MRI has been developed into an imaging modality utilized to obtain images of anatomical features of live human subjects. Such images depicting parameters associated with nuclear spins (typically hydrogen protons associated with water in tissue) may be of medical diagnostic value in determining the state of health of tissue in the region examined. The use of MRI to produce images and spectroscopic studies of the human body has necessitated the use of specifically designed system components, such as the magnet, gradient and RF coils.

Brief Summary Text (5):
In imaging techniques using the MRI phenomenon, it is necessary that the subject to be imaged remains motionless. Because known imaging techniques span time periods of typical heart and respiratory cycles, some movement of the subject is inevitable. A known method of avoiding distortion of an MR image from biological motion such as heart and lung movement, is to gate the acquisition of MRI signals to the cyclic movement of the heart or lungs. Unfortunately, in order to gate the acquisition of MRI signals to body movement such as heart or lung motion, it has been necessary to place probes on or in close proximity to the subject. This requirement results in probes being placed inside the bore of the main magnet--an undesirable situation since the probes may often generate distortions in the uniform magnetic field B.sub.0 and/or in the radio frequency field, B.sub.1, with a resulting reduction in image quality. The necessity of applying probes to the patient also reduces scanner throughput thereby increasing the cost per scan.

Brief Summary Text (8):
It is a more detailed object of the invention to provide an apparatus and method for acquiring physiological gating signals without physically contacting the body and without introducing sensors into the bore of the main MRI magnet.

Brief Summary Text (11):
In accordance with the invention, signals corresponding to physiological motion of a subject are provided by mixing generated signals with their reflections to produce a baseband signal. This baseband signal is indicative of the phase and amplitude relationships between the generated and reflected signals wherein these phase and amplitude relationships are modulated by the relative motion between the transducer and the subject being monitored. Physiological motion may be sensed by means of a resonant radio frequency (RF) coil which may be the same RF coil used to nutate nuclei during magnetic resonance imaging (MRI). Body motion modulates the quality factor (Q) of the coil and the load impedance (Z) the coil presents to the RF source. As a result of this modulation of coil characteristics by body motion, the reflection coefficient between the RF source and coil is also modulated.

Consequently, when the reflected signal is mixed (heterodyned) with the forward signal, a baseband signal results which contains information indicative of motion from internal and external regions of the body (e.g., chest wall, heart, gastrointestinal tract, etc.).

Brief Summary Text (12):
Quadrature techniques may be used to resolve the magnitude and phase of the reflection coefficient. Both these quantities contain physiological motion information. If phase information is to be used, either the reflection coefficient must be sampled at a plane where the phase is finite or the coil must be interrogated at a frequency slightly off resonance. For small motions, the phase changes in the reflection coefficient are linearly related to body motion. Small changes in the magnitude of the reflection coefficient are also linearly related to body motion. Either or both of these quantities may be used to obtain the gating signal for MRI. Changes in the resonant frequency of the coil at the MRI (Larmor) frequency or at other resonant frequencies are also linearly related to body motion and could be used to obtain the gating signal. The sensitivity of the invention to the phase and magnitude of the reflected signals is sufficient to detect the small displacement of the body surface caused by a heart beat.

Drawing Description Text (3):
FIG. 1 is a schematic block diagram of the major component elements of an MRI system according to the invention;

Drawing Description Text (4):
FIGS. 2a-d are simplified and non-rigorous waveform diagrams illustrating how waveforms indicative of physiological motion of the body derived from the invention (FIGS. 2a and 2c) can be used to synchronize acquisition of MRI signals (FIGS. 2b and 2d) with periodic movement of the body;

Drawing Description Text (5):
FIG. 3 is a schematic depiction of the RF coil in the MRI system shown in FIG. 1;

Drawing Description Text (6):
FIG. 4 is a lumped-element equivalent circuit of the RF coil illustrated in FIG. 3;

Drawing Description Text (7):
FIG. 5 is a graph of the frequency response of the RF coil, depicting the coil's primary and secondary resonances;

Drawing Description Text (8):
FIG. 6 is a schematic diagram of the preferred embodiment of the invention wherein the RF coil of the MRI system serves as a transducer in accordance with the invention for generating signals indicative of physiological movement of a patient positioned inside the MRI device; and

Drawing Description Text (9):
FIG. 7 is an enlarged view of the frequency response of the RF coil at its primary resonance in FIG. 5, showing the frequency F.sub.1 at which the RF coil is excited in order to provide signals indicative of physiological motion in accordance with the invention.

Drawing Description Text (11):
Referring to FIG. 1, overall system operation for MR imaging is under the control of a computer system generally designated 200 which includes a main computer 201, such as a Data General MV4000. The computer 201 has associated therewith an interface 202 through which a plurality of peripheral devices and other MRI system components are coupled. Among the peripheral devices which may be utilized under the direction of the main computer 201 is a magnetic tape drive 204 for archiving patient data and images to magnetic tape. Processed patient data may also be stored in an image disk storage device 210. An array processor 206 is utilized for pre-processing data and data reconstruction.

Drawing Description Text (12):
In order to provide interactive image display manipulation such as magnification, image comparison, and gray scale adjustment, an image processor 208 is joined to the main computer 201 via interface 202. The computer system 200 is provided with a means to store raw (unreconstructed) image data utilizing a disk storage system 212. An operator console 216 is also coupled to the computer 201 via the interface 202

and provides the operator with the means to input data pertinent to a patient study as well as additional data necessary for proper MRI system operation, such as initiating and terminating scans. The operator console may also include a CRT for displaying images stored on disks or magnetic tape.

Drawing Description Text (13):
Control over the MRI system is exercised by means of control and gradient amplifier systems 218 and 228, respectively. The computer 201 communicates with the system control 218 by way of a conventional digital communication network 203 (such as an Ethernet network) in a manner well known to those skilled in the art. The system control 218 includes several subsystems such as the pulse control module 220 (commonly referred to PCM), a radio-frequency transceiver 222, a status and control module 224 (commonly referred to as SCM), and the power supplies 226 necessary to energize the components of the system control 218. In response to control signals from the main computer 201, the PCM generates digital timing and control signals such as the current waveforms used for gradient coil excitation, as well as RF envelope waveforms utilized in the transceiver 222 for modulating RF pulses.

Drawing Description Text (14):
The current waveforms from the PCM 220 are applied to the gradient amplifier system 228 generally comprising G.sub.x, G.sub.y, and G.sub.z amplifiers 230, 232 and 234, respectively. Each amplifier is utilized to excite a corresponding gradient coil in a gradient coil assembly 236. When energized, the gradient coils of the gradient coil assembly 236 generate substantially linear, mutually orthogonal magnetic field gradients G.sub.x, G.sub.y and G.sub.z directed in the x, y and z-axis direction, respectively, of a cartesian coordinate system. In a manner well known to those skilled in the art, the gradient magnetic fields G.sub.x, G.sub.y and G.sub.z generated by the gradient coil assembly 236 are utilized in combination with radio-frequency pulses generated by transceiver 222 to encode spatial information into the MRI signals emanating from the region of the patient under study.

Drawing Description Text (15):
Waveforms and control signals provided by the PCM 220 are utilized by transceiver 222 for RF carrier modulation and control of the operating mode; that is, the transmit or receive mode. In the transmit mode, the transmitter 222 provides a radio-frequency carrier waveform modulated in accordance with the control signals from the PCM 220 to an RF power amplifier 223 which then energizes a RF coil 238 which is physically located inside the main magnet assembly 246. In a receive mode, the RF coil 238 senses the MRI signals radiated by the excited nuclei (a separate RF coil may be used for the receive mode if desired). The signals are detected, filtered, and digitized in the transceiver 222. The digitized signals are delivered to the main computer 201 for processing by means of a dedicated, unidirectional, high-speed digital link 205 which links interface 202 and transceiver 222.

Drawing Description Text (16):
The PCM 220 and SCM 224 are independent subsystems both of which communicate with the main computer 201, peripheral systems such as the patient positioning system 251, as well as to one another by way of the digital communication network 203. The PCM 220 and SCM 224 are each comprised of a sixteen-bit computer (such as an Intel 8086) for processing commands from the main computer 201. The SCM includes means for acquiring information regarding patient cradle (not shown) position and position of the movable patient alignment light fan beam (not shown). This information is used by main computer 201 to modify image display and reconstruction parameters (such as offset). The SCM 224 also initiates functions such as actuation of the patient alignment and transport systems 248 and 250, respectively.

Drawing Description Text (17):
The gradient coil assembly 236 and the RF coil 238 are mounted within the bore of the magnet in the main magnet assembly 246 utilized to produce the polarizing magnetic field B.sub.0. The magnet in the main magnet assembly 246 also surrounds the patient alignment system 248, a shim coil power supply 240 and a main magnet power supply 242. The shim power supply 240 is utilized to energize shim coils (not shown) associated with the main magnet assembly 246 and which are used to correct inhomogeneities in the polarizing magnetic field B.sub.0. The patient alignment system 248 operates in combination with a patient cradle and transport system 250 and patient positioning system 252 in a well-known manner.

Drawing Description Text (18):
To minimize interference from external sources, the MRI system components including

the main magnet assembly 246, the gradient coil assembly 236, and the RE coil 238, as well as the associated power supplies and patient handling devices, are enclosed in an RF-shielded room 244. The shielding is generally provided by a copper or aluminum screen network which enclosed the entire room. The screen network serves to contain the RF signals generated by the system, while shielding the system from RF signals generated outside the room. For isolating the RF signals, a bi-directional attenuation of approximately 80 db in the frequency range of operation, 10 MH.sub.z -80 MH.sub.z, is appropriate.

Drawing Description Text (19):
In accordance with the invention, a signal is generated within the bore of the MRI magnet causing an interaction of the signal with the body of the subject in the area of the body to be imaged such that a reflection of the generated signal is characterized by changes in magnitude and phase, wherein such changes are indicative of body motion and provide a basis for timing the acquisition of MRI signals. By mixing the generated and reflected signals, a single signal can be generated which is encoded with changes in the relative phase and amplitude of the two signals caused by body motion. A low pass filtering of the combined signal leaves only the slow changing phase and magnitude relationships, which are directly related to movement of the body. Specifically, the amplitude of the signal indicates the relative extent of movement, a positive or negative slope of the signal indicates the relative direction of movement and the angle of the slope indicates the speed of the movement. Further frequency filtering may separate signals indicative of heart and lung movement (or other motion) in order to provide the desired type of physiological signal for triggering acquisition of MRI data or for their own diagnostic information. Such systems are not adversely affected by moderate thicknesses of non-metallic, relatively dry clothing.

Drawing Description Text (20):
In keeping with the invention, the MRI system of FIG. 1 includes a transmit and receive transducer assembly 252 within the RF-shielded room 244 for providing the aforementioned electronic signal indicative of physiological movement of the patient for use in triggering or gating the pulse sequence. The signal from the transducer assembly 252 supplies to the SCM 224, via the RF transmitter 254, and phase detection 256, an indication of body motion from which trigger pulses are generated for synchronizing the patient's physiological movement with the scanning time associated with the MRI pulse sequence. Preferably, the RF transmitter 254 and phase detector 256 provide respiratory or cardiac signals or other gating signals to the SCM 224. The SCM 224 uses these signals to initiate the pulse sequence at the PCM 220 during times of minimum body movement. While diagnostic quality signals are not required from the RF transmitter 254 and phase detector 256, the signal must enable the SCM 224 to recognize time of no or little physiological motion and/or to recognize a particular position in the physiological motion cycle for imaging during various points in the cycle.

Drawing Description Text (22):
Referring to FIG. 2, the SCM 224 of FIG. 1 may control the initiation of an MRI signal sequence and data acquisition S.sub.I at times .DELTA.t of slow or other periodic positions of chest movement (FIGS. 2a and 2b) or times .DELTA.t' of slow or other periodic positions of cardiac movement (FIGS. 2c and 2d), depending upon which movement best characterizes the desired position of the imaging slice. Although the waveforms of FIGS. 2a-d are not intended to be a rigorous depiction of respiratory or cardiac motions, they serve to illustrate that a signal indicative of body motion may serve as a means for isolating portions of cyclic physiological movements in order to gather MRI signals for a signal image over a plurality of cycles such that the final image is not blurred by the motion.

Drawing Description Text (25):
In practicing the invention, the RE coil 238 of FIG. 1 preferably provides the function of the transducer assembly 252 in addition to its task of providing the RF signals for MR imaging, thereby eliminating the requirement of adding a new element to the system and its introduction into the sensitive environment of the imaging system. For example, the single-turn saddle coil illustrated in FIG. 3 is a particular RF coil used in MR imaging comprised of two parallel conductive segments 21a and 22a each having a capacitor 23a connected in series therewith. The ends of conductors 21a and 22a are connected to diametrically opposed points on a pair of parallel conductive loops 25a and 26a spaced apart along common longitudinal axis 16.

Drawing Description Text (26):
For MR imaging, the RF coil 238 is driven by the transceiver 222 which is illustrated as an RF amplifier 20 in FIG. 3 connected between terminals 27a and 28a in parallel with the capacitor in segment 21a. Arrows 29 indicate the relevant current paths which produce a B.sub.1 radio-frequency field perpendicular to the plane defined by conductive wire segments 21a and 22a which, for convenience, will be hereinafter referred to as being vertical. Although various coupling methods may prove to be the most appropriate for a particular imaging system, the most probable coupling of the signal for acquiring physiological data to the RF coil is a conventional RF coupling. To implement the coupling, the RF signal for physiological data may simply be RF coupled in a conventional manner to the output of the RF amplifier 20. In some particular implementations of the invention--particularly those using resonances of the RF coil higher than the primary resonance used for imaging--coupling may best be provided by a small exciting coil (not shown) mounted adjacent the RF coil 238.

Drawing Description Text (27):
A better understanding of the RF coil depicted schematically in FIG. 3 can be acquired by study of the lumped-element-equivalent circuit for this coil configuration as shown in FIG. 4. The equivalent circuit is a balanced-ladder network generally designated 30. The network is comprised of inductive elements 31 and 32, having connected at one of its ends a series-connected combination of inductive and capacitive elements 33 and 34, respectively. The two points labeled A are joined together to complete the upper conductive loop 26a, and the points labeled B are joined to complete the lower conductive loop 25a. Inductors 31 and 32 represent the inductance associated with each loop 26a and 25a, respectively. Likewise, inductor 33 is associated with vertical wire segments 21a and 22a. At a frequency F.sub.R1 where the cumulative phase shift for the network 30 adds to 2.pi. radians, the coil has a standing wave resonance. This resonance is commonly referred to as the primary resonance.

Drawing Description Text (29):
When a patient is introduced into the imaging device, the patient's body is positioned within the cylinder defined by the RF coil. At frequencies close to the primary resonance of the coil, the predominanting effect of the body on the RF coil is one of impedance which loads the coil. By modeling the body as an impedance R and the RF coil 238 as an effective inductance L and capacitance C as shown in FIG. 6, the interaction between the RF coil and the body can be quantitatively analyzed. The foregoing assumes the effective impedance of the coil to be negligible relative to the effective impedance of the body.

Drawing Description Text (30):
By modeling the RF transceiver 254 of FIG. 1 and its associated electronics (a power splitter 52 and directional coupler 54) which aid in generating and receiving an RF signal as a signal generator 50 with an output impedance Z.sub.O, the body and coil may be characterized as having a complex impedance Z.sub.L which is not necessarily equal to Z.sub.O. Since the predominate effect of the body is to load the coil according to the body geometry and the body's fill factor (i.e., the volume and density of the body), the complex impedance of the RF coil changes as the body wall moves (due to heartbeat, respiration, and other body motions).

Drawing Description Text (31):
In the model of FIG. 6, the phase detector 256 of FIG. 1 is implemented by a double-balanced mixer 50 operating in the square law region. In a conventional manner, the power splitter 52 redirects a portion of the RF signal V.sub.G generated by the RF source 56 to the mixer 56. Also in a conventional manner, the directional coupler 54 directs the received signal V.sub.r, reflected by the impedance mismatch, to the mixer 56. The signal generated by the mixer 56 includes the baseband signal which carries the physiological motion indications. By passing the signal through a low-pass filter 58, the RF frequency is removed from the signal, leaving only the more slowly changing baseband signal whose slope and magnitude can be directly related to physiological movement.

Drawing Description Text (33):
For a detection technique exemplified by FIG. 6, the baseband signal includes both phase and magnitude changes of the reflected signal. Both the magnitude and the phase of the reflected signal change as a function of changing impedance Z.sub.L (caused by body movement). If it is desirable to use only phase or magnitude information from the baseband signal to trigger the MRI data acquisition sequence,

known quadrature techniques may be used to resolve magnitude and phase from the reflected signal.

Drawing Description Text (34):
It is possible to interrogate the body with a frequency F.sub.1, near the primary resonant frequency F.sub.R1 of the RF coil, but beyond the bandwidth .DELTA.F of the imaging system as indicated by FIG. 7. At the frequency F.sub.1, the coil is still characterized by a high Q value (i.e., quality factor), but the frequency should not interfere with the coil's functioning at the RF frequency for imaging. It is also possible to interrogate at some of the secondary resonances of the RF coil provided that the field structure is such that body movement significantly modulates the coil impedance. Preferably, the RF coil is not excited at the central frequencies since little if any phase information is available at these frequencies. Although FIG. 5 indicates the secondary resonances of the RF coil are all at higher frequencies than the imaging resonances, lower secondary resonances may also be used to excite the coil if they are available.

Drawing Description Text (38):
Associated with the amplitude of the reflected signal indicated by the reflection coefficient .rho. is an angle .phi. which represents a phase difference between the incident and reflected voltage. For the RF coil, the angle .phi. may be expressed as follows: ##EQU4## where Z.sub.R is the real part of the complex impedance Z.sub.L of the RF coil and the body. The angle .theta. is the phase angle between the real and imaginary components of the complex impedance.

Drawing Description Text (40):
More generally, the admittance of the body and RF coil can be characterized as, ##EQU6## where .omega. is the frequency at which the RF coil is excited.

Drawing Description Text (44):
In keeping with the invention, the angle .rho. and/or magnitude .vertline..rho..vertline. can be measured by exciting the RF coil at a frequency F.sub.1 within the primary high Q region of the coil but outside the bandwidth of the MR imaging as indicated in FIG. 7 or, alternatively, at a frequency F.sub.R2 through F.sub.Rn (FIG. 5) which is near a different harmonic resonance of the coil. For example, if the RF coil is tuned for primary resonance at 63.87 MHz and the imaging process utilizes a bandwidth .DELTA.F of 32 KHz centered about 63.87 MHz, a frequency F.sub.1 outside the bandwidth, but still within the high Q area of the coil's response (approximately 2 MHz in bandwidth), may be used to excite the coil and provide a reflected signal whose phase angle .phi. and magnitude .vertline..rho..vertline. can be measured. If practical considerations prevent the use of this frequency region (i.e., if the excitation affects image quality), the frequency may be shifted to a different harmonic resonant frequency such as 630 MHz.

Drawing Description Text (45):
The power delivered to the RF coil can be at less than one watt and still provide good quality data from the reflected signal. By the ability to perform satisfactorily at low power, the invention is less likely to disrupt the imaging process and therefore may operate in a continuous mode.

Drawing Description Text (46):
If system requirements make it undesirable for the RF coil 238 to provide the functions of the transducer assembly 252 (e.g., the extra RF signal effects image quality), a separate directional radiator, such as a horn antenna, may serve as the source of RF radiation for detecting body motion. In practicing the invention using a horn antenna, the same antenna may receive the reflected signals in a conventional manner by simply providing the antenna with a circulator. If the presence of a ferrite device such as a circulator proves to be undesirable, separate transmit and receive antennas may be used to perform the necessary functions of transmitting and receiving. Obviously if a directional radiator is employed, the available frequencies are no longer limited to the primary and secondary resonances of the RF coil 238.

Drawing Description Text (47):
Preferably, the horn antenna is located outside the radius of the RF coil and within the radius of the gradient coil. Any conventional mounting apparatus may be used for the antenna such that the horn of the antenna is fixed to the frame of the housing for the MR magnet. The antenna must be directed toward the imaging area and the

beamwidth should be sufficiently wide to cover the area but not so wide as to make the reflected signal susceptible to noise generated from near-by devices.

Drawing Description Text (48):
The propagating signal, V.sub.p, from the antenna may be expressed as:

Drawing Description Text (49):
where ".omega." is the frequency of the signal expressed in radians, "A" is the peak amplitude of the signal, and "t" is the time. The reflected signal, V.sub.R, received by the antenna may be expressed as:

Drawing Description Text (51):
It can be easily visualized that the distance, R, from the radiator to the body of the subject can be described in terms of the wavelength .lambda. of the propagating wave:

Drawing Description Text (53):
The velocity of an electromagnetic wave propagating through air can be approximated to be the speed of light, c. For a reflected wave to return to its source, the horn antenna, it first propagates a distance R to the body, reflects off the body and travels a distance R back to the antenna. Therefore, the total time delay, .tau., for a reflected wave can be expressed in terms of the distance traveled by the wave and its speeds as follows:

Drawing Description Text (54):
Because the speed of the propagating signal can be considered constant, any changes in .tau. directly reflect changes in the distance R. Therefore, as the body moves within the bore of the MR magnet, the value of .tau. should also change in a linear relationship with changes in the distance of the body from the RF coil.

Drawing Description Text (57):
The frequency of the reflected signal, .omega., can be rewritten in terms of the wavelength .lambda., and so also can .tau., as indicated by equation (19), so that the argument in equation (21) becomes:

Drawing Description Text (59):
If the position of the body is such that the cosine function is maximum, then small displacements of the body from this position result in relatively small voltage changes (ignoring changes in the magnitude AB which may be caused by body movement.) If the position is such that the value of the cosine function is zero, then relatively large changes in the received voltage will result from small displacements from this position. Since the cosine goes from its maximum value to zero as its argument varies by .pi./2 radians, the system varies from minimum to maximum sensitivity as the range varies by an eighth of a wavelength (an eighth instead of a fourth because the reflected wave must travel a total distance of 2R).

Drawing Description Text (60):
This property of variable sensitivity is not always a problem; however, if it proves to be objectionable, then the addition of a second channel in quadrature with the first (a sine channel) and the addition of appropriate signal processing eliminates the positional sensitivity dependence. The sensitivity is eliminated by taking the inverse tangent of the ratio of the channels to obtain an unambiguous phase relationship. The relative magnitude of the reflected signal can be obtained by taking the square root of the sum of the squares of the two channels, if desired.

Drawing Description Text (62):
where .theta. is the (half-power) beamwidth in degrees and d is the dimension of the aperture in the plane of interest. Clearly it is desirable to use a beamwidth sufficiently broad that alignment with the target (i.e., the body area of the imaging slice) is not difficult, and simultaneously the beamwidth should be sufficiently narrow to avoid picking up unwanted vibration sources such as the gradient coils, air conditioning ducts, or electric lights; although, these may be filtered out if they have no frequency components near the respiration or heart rate.

Drawing Description Text (63):
For frequencies around the primary resonance frequency, the angle .theta. is quite large unless the aperture is made to a size which is impractical in the MR device. Therefore, the use of directional radiators such as horn-type antennas is

practically limited to higher frequencies which approach or are within the microwave region.

Drawing Description Text (64):
A preferable horn radiator is a Gunn-diode operated in the gigahertz region. Experiments have shown that at 35 GHz using a six-inch diameter dielectric lens and a 100 mW, Gunn-diode source, heartbeat and respiration waveforms can be acquired at grazing angles of incidence outdoors at ranges of at least 150 feet even though the heartbeat displacements were on the order of a micron. Thus, very low power levels are sufficient for the ranges involved in an MRI system. Inexpensive, Gunnplexer systems are available at frequencies up to roughly 20 GHz. Some include quadrature capability.

Drawing Description Text (65):
Ultrasonic systems may alternatively provide a source of propagating waves. Such a system may also utilize a single transducer provided that the transmit transducer forms one leg of a bridge circuit (balanced under anechoic conditions) and the receiver circuit input is at the balance point of the bridge circuit. Otherwise, they are designed with an amplifier in the received signal leg. Ultrasonic systems tend to be inexpensive to build, can be operated at frequencies which have very small wavelengths (and thus permit narrow interrogating beamwidths and higher sensitivities to a given displacements), and they are attenuated by air (thus making the system less sensitive to objects outside the region of interest). Unfortunately, ultrasound is attenuated by clothing (the attenuation increases with the square of the frequency) and so several thicknesses of a blanket over the region of interest may prove to be a serious impediment of gating signal acquisition.

Drawing Description Text (67):
From the foregoing, it will be appreciated that a method is disclosed for sensing body motion in an MRI system which is non-invasive with respect to the imaging area. Unlike prior approaches, a sensor need not be placed near or on the body of the subject in order to collect data indicative of the subject's physiological motion. Furthermore, in the preferred embodiment, no additional apparatus is required within the screen room since the RF coil itself serves as the sensor for collecting the physiological data in accordance with the inventive method. By having no need for a sensor to invade the imaging area in order to obtain data indicative of physiological motion, the risk of affecting the MR image from the presence of a sensor is effectively eliminated by the invention. The elimination of a probe within the magnet bore is of considerable importance since the presence of a probe necessarily causes some disruption of the magnetic field of the magnet and, as is well known in MR imaging, the quality of an image provided by a system is greatly affected by the degree of uniformity in the system's magnetic field.

CLAIMS:

1. A method of acquiring data related to motion of a subject within a coil of an MRI device for use in the acquisition of MR data for imaging a region of said subject, said method comprising the steps of:

generating from a stationary source within said MRI device a signal of a predetermined frequency .omega. which interacts with said subject;

sensing any portion of said generated signal of frequency .omega. which is returned to said source;

comparing the characteristics of the generated signal and the reflected signal to produce a primary waveform, comprised of phase and magnitude differences between the generated and returned signals such that the extent, direction and speed of the motion is reflected in the characteristics of said primary waveform;

processing said primary waveform so as to provide a derivative waveform indicative of the physiological motion of said subject wherein the extent of said motion is reflected in the amplitude of said derivative waveform and the direction and speed of the motion is reflected in the slope of said derivative waveform, said processing including the step of removing any sensitivity of said derivative waveform characteristics to the position of said subject relative to said stationary source; and

delivering said derivative waveform to a diagnostic instrument associated with said

MRI device for use in synchronizing acquisition of MR data with the motion of said subject.

2. A method as set forth in claim 1 wherein the derivative waveform triggers an MRI sequence for acquiring imaging data.

3. A method as set forth in claim 1 wherein the step of generating a signal of a predetermined frequency .omega. includes providing an electromagnetic wave whose source is an RF coil surrounding the imaging region.

4. A method as set forth in claim 3 wherein said RF coil also generates the signals used to acquire MR data from the imaging region.

5. A method as set forth in claim 3 wherein the step of sensing any portion of said generated signal includes the detecting of an interaction between said RF coil and said subject such that motion by said subject changes a quality factor of said RF coil which in turn changes the phase and magnitude of the returned signal.

6. A method as set forth in claim 1 wherein the step of generating a signal of predetermined frequency .omega. includes providing an electromagnetic wave whose source is a transducer assembly positioned within a bore of a main MR magnet but at a radius of the bore which is approximately equal to or greater than the radius of an RF imaging coil associated with said MRI device.

10. A method as set forth in claim 9 wherein the step of combining said primary and complementary waveforms includes the step of taking the inverse tangent of the ratio of said complementary and primary waveforms.

11. In an MRI system having a main magnet with a central bore and a RF coil for generating RF signals which excite nuclei in an image region of a subject positioned in the bore of said main magnet so as to generate MR data for acquisition by said system, a method of providing data indicative of the physiological motion of the subject, said method comprising the steps of:

exciting said RF coil with an RF source at a first frequency different from a second frequency used to acquire MR data;

sensing a portion of said first frequency which is reflected by said coil back to said RF source;

comparing the characteristics of the reflected signals with those of the generated signals to produce a trigger signal indicative of relative changes in the characteristics of the generated and reflected signals such that the magnitude of said trigger signal is approximately linearly related to the extent of physiological motion in the imaging region and the slope of said trigger signal is approximately linearly related to the direction and speed of the physiological motion in the imaging region; and

triggering acquisition of MR data in response to said trigger signal so as to generate an MR image which is not blurred by the physiological motion of said imaging region.

15. A method as set forth in claim 11 wherein said RF coil is continuously excited at said first frequency during acquisition of MR data.

16. A method as set forth in claim 15 wherein said signals of first frequency are outside an imaging bandwidth of the MRI system but within a resonance of said RF coil.

18. A method as set forth in claim 11 wherein said different frequency is near the radio frequency used to acquire MR data, but outside the bandwidth of the MRI system.

19. A method as set forth in claim 11 wherein the radio frequency for acquiring MR data is within a primary resonance of said RF coil and said different frequency is within a secondary resonance of said RF coil.

20. In a MRI system, an apparatus for acquiring data related to the physiological motion of an imaging region of a subject, said apparatus comprising:

means (1) for generating a signal by exciting an RF coil of said system at a frequency .omega..sub.1 different from a frequency .omega..sub.2 used by said MRI system to excite said RF coil for acquisition of MR imaging data;

means (2) for sensing a portion of said signal at the frequency .omega..sub.1 reflected by said RF coil as a result of the interaction of the generated signal with the RF coil and the subject;

means (3) for comparing the generated and reflected signals at the frequency .omega..sub.1 to provide a trigger signal at the frequency .omega..sub.1 whose characteristics are linearly related to the physiological motion of the imaging slice; and

means (4) for receiving the trigger signal and in response thereto signal the acquisition of MR data so that the image of the slice is not blurred by the physiological movement of the slice.

L19: Entry 62 of 63 File: USPT Jan 31, 1989

DOCUMENT-IDENTIFIER: US 4802008 A
TITLE: Satellite communications system for medical related images

Brief Summary Text (4):
Systems are well known for sending medical related images, such as X-rays, ultrasound, computerized tomography (CT), nuclear magnetic resonance (NMR), EKG, etc., over phone lines and standard television communication systems. These existing medical communications systems, however, suffer from a number of disadvantages, including high costs, immobility, inaccuracy, and slow transmission communication.

Brief Summary Text (5):
The cost of sending high resolution images over phone lines is expensive due to the high costs associated with operating a phone link system. Slow transmission rates over the phone lines (9600 baud rate maximum) further causes phone charges to accumulate over time. Also, digitized images sent over phone lines must be encoded with extra parity bits to insure against errors caused by noise (20 db signal to noise ratio) during transmission. Analysis of the extra bits causes further delay in transmission. Often, errors are not detected and the images are sent with the inaccuracies anyway. In these situations doctors are left with evaluating images that have inaccuracies. Thus, the analysis provided by the doctor is inadequate due to the inaccuracies of the image. Furthermore, phone link systems cannot easily provide communication with mobile units. It is desirable to have mobile units capable of developing medical photographs and capable of sending the photographs from any location to a central headquarters, where these images can be diagnosed by a professional. However, phone link systems are constrained in that not all locations can provide the proper phone line hookups for sending the medical images to the central headquarters.

Brief Summary Text (11):
By converting only static or single frame images, this invention overcomes the drawbacks of the prior art. Essentially, because the image does not move, (i.e., x-ray, etc.), the transmitting equipment can take more time to break down the static image and it can send a low frequency/narrow band width signals at a slower rate, thereby reducing the cost of sending images traditionally associated with standard television communication systems. This invention uses the lowest possible frequencies and narrowest possible band width to achieve the highest quality transmission of the images available, thereby keeping costs low. Additionally, the system can achieve the transmission more accurately at a 65 db signal to noise ratio and in less than 1/12 the time it takes a phone line system to operate.

Detailed Description Text (2):
Referring to FIGS. 1A, 1B and 1C, a mobile truck 10 is shown transmitting low frequency/narrow band width signals to a satellite 12 which in turn transmits the low frequency narrow band signals to a central headquarters 14. Truck 10 contains equipment for generating medical related images, such as the X-ray equipment 16 as shown. The truck can also accommodate ultrasound equipment, magnetic resonance equipment, echo cardiogram equipment, etc. For discussion purposes only, however, we will focus primarily on transmitting photographic images produced by X-ray equipment 16.

Detailed Description Text (3):
Truck 10 contains image conversion and communications equipment 18. Referring to FIG. 1B, this equipment includes a receiving and transmitting satellite antenna control (not shown), a high resolution camera 22, a light table 24, monitor 28, thermal printer 30, impact printer 32, video compressor 50, modulator/demodulator 52

and 72, computer 33 and head phones 74. Truck 10 also includes a dark room for developing medical photographs (which is not shown). The top side of the truck 10 includes a satellite antenna 34 for communication with the central headquarters 14. Although only one truck is shown in FIG. 1, any number of trucks 10 are capable of communicating with the central headquarters 14 or to the other trucks from any given location throughout the world.

Detailed Description Text (4):
Central headquarters 14 consists of a receiving and transmitting satellite antenna 36 and headquarters 37. Referring to FIG. 1C, the equipment for analyzing the received radio signals from the mobile truck 10 is shown. Receiving equipment 38, consisting of a demodulator 54, video expander 56 and buffer 58, is linked to monitors 40, 42 and to personal computer 44. The personal computer 44 is linked to mass storage 62, frame store 64, and modulator 70 which is linked to satellite antenna 36 in FIG. 1A.

Detailed Description Text (6):
More particularly, referring to FIG. 1B, an operator of the truck 10 takes a developed X-ray and places it on light table 24 for reviewing by a high resolution camera 22. High resolution camera 22 takes a video photograph of the X-ray and this image is converted into an analog voltage signal by video compressor 50. FM modulator 52 then converts the analog signal into a low frequency narrow band signal to be transmitted by satellite dish 34 (FIG. 1A). The signal is sent to satellite 12 where it is resent to the central headquarters satellite antenna 36. Truck 10 and the central headquarters 14 can be at any distance from each other. For example, a mobile truck in the flat plains of the desert in Arizona could transmit images by satellite to a central headquarters located in Southern California.

Detailed Description Text (7):
At the central headquarters 14 (FIG. 1A), the transmission signal is converted into an analog voltage signal by demodulator 54 and then converted into a digital image at video expander 56 (FIG. 1C). In the preferred embodiment, high resolution monitors 40, 42 are capable of displaying two different static x-ray images transmitted from the truck 10. A radiologist can then review the images displayed on the high resolution monitors 40, 42 and provide his diagnosis of the X-rays directly to the mobile truck via satellite, in either voice or readable form. Microphone 48 converts the doctor's verbal diagnosis into an analog signal which is sent directly to FM modulator 70, where it is converted into a frequency signal to be sent over satellite antenna 34 (FIG. 1A) to truck 10. Additionally, computer 44 is capable of converting the doctor's verbal analysis directly into digital text, which can be separately FM modulated and sent to truck 10.

Detailed Description Text (9):
Referring to FIG. 2, a block diagram representation of the preferred embodiment of the system is shown. As discussed above, the truck 10 consists of image conversation and communications equipment 18 and satellite antenna 34. The image conversation and communications equipment can be further broken down into high resolution camera 22 and transmission equipment 21. The transmission equipment includes a video compressor 50 and modulator 52. Starting with block 22, a high resolution photograph of, for example an X-ray, is taken. High resolution cameras are well known to those skilled in the art and in the preferred embodiment, the high resolution camera 22 is a 68 -Series MTI .TM. camera designed and built by Dage-MTI Inc. In the preferred embodiment, the high resolution camera has 512 X 512 picture elements or pixels and for even higher resolution the camera has 1,024.times.1,024 pixels. Each picture element or pixel is essentially a small light detector for sensing the intensity of light at a given location. The more pixels there are on the charged coupled array (not shown) of the camera, the better the quality of the image recorded. The camera is also equipped with a focus and zoom control so that an operator can adjust the camera to obtain any desired view of the X-ray image. Additionally, it is envisioned that a doctor at the central location 14 (FIG. 1A) will be able to control the positioning, zoom and focus of the high resolution camera 22.

Detailed Description Text (14):
As stated, when the analog signal is being generated by the video compressor it is also simultaneously sent to the FM modulator 52. The FM modulator essentially converts this voltage analog signal into a frequency signal which is acceptable for standard radio transmission equipment. In the preferred embodiment, the zero voltage range of the voltage analog signal is represented by an 11 KHz band width signal and the maximum voltage is represented by a 15 KHz signal.

Detailed Description Text (15):
Essentially, the truck 10 acts as a standard FM radio station, converting the 11-15 KHz band width signal into an FM transmission. The frequency signal representative of the voltage analog signal is sent via a satellite antenna 34 at approximately an occupied band width of 180-200 KHz band width. At this band width, the signal to noise ratio of the system is 65 db. For a lower signal to noise ratio a greater deviation from the 11-15 KHz signal is made (e.g. 220-246 Khz occupied band width signal). Satellite 12 essentially acts as a repeater translating the transmitted signal into a different frequency and then sending it to satellite antenna 36 at central headquarters 14. The satellite antenna 36 is equipped with an FM filter to ensure that the receiving equipment only receives the transmitted signals from the satellite. For a more detailed description of the preferred embodiment of satellite disk antenna 34,36 satellite 12 and, refer to Appendix II. The signal is then sent to the receiving equipment 38 where demodulator 54 converts the frequency signal back to an analog voltage signal.

Detailed Description Text (19):
When the digital data is displayed on monitor 60, a doctor analyzes the displayed image and provides his diagnosis via a voice activated computer 44. An analog voice signal of the doctor's diagnosis is sent to modulator 70 for transmission or a digital text signal is sent to modulator 70 for transmission back to the truck 10. Additionally, the digital text signal is also sent to the mass storage device 62 for storage and/or future reference. For transmission of the diagnosis to truck 10, modulator 70 converts the voice or digital signals into a narrow band width/low frequency signal. Satellite dish antenna 36 then transmits the frequency signal to the satellite 12 which in turn repeats a different frequency signal to the satellite antenna 34 of truck 10. The narrow band width/low frequency signal representative of the voice signal or the digital text signal is then converted back to an analog or digital signal by demodulator 72 on truck 10. The digital text signal is processed and formated by computer 33 and then it is displayed on a standard monitor 28 or printer 32, the textual analysis is provided to printer 32, so that the operator has a record of the diagnosis. If voice signals are sent, then the analog voice signal is sent from demodulator 72 directly to head phones 74. The instructions and analysis provided by the doctor will then be used by the operator/nurse to administer treatment if necessary.

Detailed Description Text (20):
Up until now, a satellite communications system for sending narrow band width/low frequency signals representing voltage analog signals of video images has been described. Referring to FIG. 4, another embodiment is depicted for transmitting a frequency signal representative of a digital signal instead of a voltage signal. The only difference in the embodiments depicted in FIGS. 2 and 4, is that the video expander has been moved from the central headquarters 14 into the truck 10. Now when the video compressor 50 generates a voltage analog signal a video expander 56 will convert the analog signal into a digital signal. As mentioned previously, the voltage analog signal produced by the video compressor represents pixel gray scale values for the vertical columns of pixels in the high resolution camera. The video expander converts the voltage signal into a binary number from 0 to 256. Each binary number represents a digital signal to be converted by the FM modulator 52 into a narrow band/low frequency signal. Essentially, the video expander acts as an analog/digital converter, changing the voltage signal of the video compressor into a digital signal for FM modulation. Satellite antenna 34, on truck 10, sends the narrow band/low frequency signal to satellite 12. Satellite antenna 36 at the central headquarters 14 receives the signal reflected by the satellite 12. The frequency signal is then converted into a digital signal by the demodulator 54. Unlike the other previously described embodiments, a video expander need not be provided because the signal is already represented in its digital form. However, a buffer is still required to delay the data before it is sent to monitors 60. All other parts of this embodiment are identical to the embodiment shown in FIG. 2.

Detailed Description Text (21):
The invention has been described in exemplary and preferred embodiments, but is not limited thereto. Those skilled in the art will recognize that a number of additional modifications and improvements can be made to the invention without departure from the essential spirit and scope. For example, the preferred embodiment of the invention may be used to send other medical related images, such as CT, magnetic resonance and ultrasonic sound images, etc., from the truck to the central headquarters or vice versa. Additionally, the resolution of the images provided are

only limited by the resolution of the camera and monitors available to the art. Therefore, the invention is not limited by the above disclosure, but only by the following claims.

Detailed Description Text (24):
The Video Compressor is intended to function as the transmitter in a narrow-band (sometimes called "slow-scan") video communications system. It accepts a standard, composite TV signal and reduces the signal band width to the audio range for transmission over narrow-band communication channels. The video compressor requires a channel band width of 11-15 KHz and transmits a picture in 9 to 30 seconds depending on the resolution required. The video compressor operates over voice grade FM modulated band frequency channels and requires 8 seconds for 256.times.256 resolution, 16 seconds for 512--512 resolution.

Detailed Description Text (40):
(II A) Dish Antenna Deployment

Detailed Description Text (45):
(1) To raise the dish antenna from its storage position to its operational position, first select the power system to be used. When connected to shore or auxiliary generator power, first verify that the "utility light" breaker on the Power Distribution Panel is on. Next move the "Pan-Tilt Power" switch on the Power Distribution Panel to the AC position. If the truck is not connected to the shore power and the generator is not being used, move the "Pan-Tilt Power" switch to the Inverter position.

Detailed Description Text (47):
(3) Depress the "UP" button located beneath the enable switch until the dish antenna is raised to its full operational position and stops automatically. Aiming

Detailed Description Text (50):
(3) It is necessary to know the polarization of the desired transponder prior to transmission. The "V" or "H" buttons on the Hubcom MS-2 will then route the waveguides to provided the corresponding vertical or horizontal feed port for the received signal. The transmitted signal will be automatically routed ot the orthogonal feed port.

Detailed Description Text (52):
To return the dish antenna to the storage position, simply depress the "stow" button on the "AP-1" unit. The dish antenna will center and lower itself to the storage position automatically.

Detailed Description Text (53):
Dish antenna positioning is controlled from the operator area and is greatly simplified by digital readouts of elevation and azimuth on the dish aming control panel. Once the disk is roughly positioned, the transponder frequency selected and correct polarization of the feedhorn chosen watch the spectrum analyzer while slowly panning the dish in a systematic pattern until a sight display of an active transponder is seen. All satellites have characteristic spectral energy distribution. Check for narrow band communications channels, half transponder operation, scrambled signals and narrow band beacons.

Detailed Description Text (57):
(II-B) RF Terminal

Detailed Description Text (58):
The terminal transmits at 14.0-14.5 GHz and receives at 11.7-12.2 GHz. It consists of a microwave transceiver, power supply unit, and ac and dc cables.

Detailed Description Text (59):
The preferred RF terminal is an ASAP 12161 Terminal provided by Avantek designed to interface with any modern dish having a data capability of 9.6 kbps to 1.544 <bps and any size antenna. It is used in a wide range of data distribution and collection applications, including financial data transfer, oil well and pipeline monitoring, point-of-sales systems, electronic funds transfer, electronic mail, voice store-and-forward communications, and video conferencing.

Detailed Description Text (60):
The function of the ASAT 1214 RF Terminal is the upconversion of the modulators's IF

output to an RF signal for transmission via an antenna, and the downconversion of the received RF signal for use by the demodulator. Major components are an upconverter chain, a low-noise downconverter, and a frequency synthesizer. The power amplifier in the upconverter chain is made of Aventek's Gallium Arsenide Field Effect Transistor (GaAsFET) devices and Internal Matching network (IMFET) devices that provide highly stable power gain and minimal intermodulation distortion. The downconverter is built around low-noise amplifier devices, providing a system noise temperature of better than 250.degree. K. The synthesizers rely on an ovenized 10 MIIZ crystal oscillator which provides fully synthesized carrier frequency selection in 1 MHz steps over a 500 MHz bandwidth.

Detailed Description Text (61):
RF TRANSCEIVER

Detailed Description Text (62):
The RF transceiver, upconverts a 70 MHz IF signal from a modulator to a 14 GHz transmit signal. The upconversion process used two upconverters, a bandpass filter, and a power amplifier, and is controlled by an automatic level control (ALC) circuit. On the receive side, the transceiver downconverts a 12 GHz received signal to a 70 MHz IF signal for output to a demodulator. Key downconversion modules are a 12 GHz bandpass filter and a low-noise converter. Both conversion functions rely on LO signals processed by a fixed synthesizer. The system parameters are monitore by an internal summary alarm board.

Detailed Description Text (63):
The IF transmit signal enters the transceiver at a frequency of 70 MHz +20 MHz. In the first upconverter, this IF signal mixes with a 1150 MHz LO signal to produce a 1220 MHz (.+-.20 MHz) IF signal. After passing through a 1220 MHz bandpass filter, the signal is mixed in the second upconverter with a 12.78-13.78 GHz agile LO signal. When summed with the IF signal, the LO signal will produce a transmit signal with the desired RF frequency in the 14.0-14.5 GHzband.

Detailed Description Text (64):
The RF transmit signal is amplified by the power amplifier as a final step before transmission. Active bias regulators in the power amplifier ensure that each stage of amplification is performed at very nearly the optimum point regardless of temperature environment. A 2W power amplifier raises the RF signal to the output power of 23 dBm to 33 dBm, depending on the setting selected during alignment. The selected output level is held constant by the automatic level control loop, consisting of a control circuit in the first upconverter and a level detector in the power amplifier.

Detailed Description Text (70):
All of the transceiver's functions are monitored by alarm circuitry which activates light-emitting diodes (LEDS) on the summary alarm board. The LED alarms allow detection of power failure, loss of lock, extreme temperature, and failure of any one of the functional components in the transceiver.

Detailed Description Text (72):
In the preferred embodiment, the satellite system is a GStar satellite network. It is a telecommunications system owned and operated by GTE Satellite Communications, and it is composed of three orbiting satellites. GStar A1 was successfully launched by an Ariane rocket on May 7, 1985. GStar A2 is scheduled to be launched in December 1985 or January 1986. These satellites are the first U.S. Ku-band communications spacecraft to offer 50-state coverage at 12 GHz, as well as regional beam coverage to the eastern or western halves of the continental United States. The GStar A2 and A3 satellites will also have the ability to transmit by way of two, high-powered spot beams.

Detailed Description Text (73):
Each GStar satellite carries 16 transponders with usable band widths of 54 MHz. Fourteen 20-watt transponders can be switched between east or west regional beams or CONUS coverage. The remaining two 27-watt transponders are connected to a combined footprint that covers CONUS, Alaska, and Hawaii. Because of their wide band widths, GStar transponders are capable of transmitting two simultaneous TV programs on multiple data and voice circuits.

Detailed Description Text (74):
Fourteen of GStar's 16 operational transponders use 20-watt TWTAs that can be

tailored by ground command to provide east or west regional coverage or 48-state (CONUS) coverage. The remaining two transponders provide 50-state coverage using combined CONUS/Alaska/Hawaii beams powered by 27-watt TWTAs. The antenna subsystem comprises two offset parabolic reflectors. Polarization purity if achieved through the use of grids embedded in each reflector that are transparent to the opposite sense of polarity.

Detailed Description Text (76):
Another embodiment of the satellite network is a Hughes Galaxy which operates a Ku-band satellite system starting in 1987. The system consists of two in-orbit satellites providing coverage of the 48 contiguous states. Hughes Galaxy receives orbital assignments of 71 and 180 degrees west longitude. Galaxy K-band satellites will use the Hughes Aircraft HS 393 wide-body design derived from the Intelsat* VI spacecraft bus. Individual satellites within the system carry 16 active transponders with usable band widths of 52 MHz. Each transponder is connected by ground command to one of two shaped full-CONUS beams, or to an east or west half-CONUS beam.

Detailed Description Text (80):
Signal-to-Noise Ratio: 60 db or better.

Detailed Description Text (81):
In the receiving mode, the Video Expander accepts properly formatted slow-scan TV input signals and reconstructs a conventional TV still picture using the same memory which provided frame freeze for transmission. Image retention is indefinate unless deliberately erased or power to the Video Expander is lost. A remote control box is provided for easy desk top operation. The unit can be generally locked to other video sources to provide switching, mixing, and special effects capabilities.

Detailed Description Paragraph Table (1):

SPECIFICATIONS Size: 51/2" .times. 17" .times. 13" Weight: 11 lbs. Mounting: Stand alone (rack mount optional) Power: 117/230VAC, 50/60 Hz, 20 VA Input: Composite video; 1 volt p--p, 75 ohms (525-line or 625-line, 2:1 interlace) Outputs: Slow-scan video; adjustable 0 to 6 volts max., 600 ohms, white positive Video; Composite, 1 V p--p, 75 ohms Controls: Video Level Black Level Output Level Analyze (position) Single/Continuous (Optional) Start Connectors: Video, BNC Slow-scan output; 5 pin, Amphenol 126 series Performance: Band width; 4 MHz monial, to match receiver resolution capability and to minimize noise. Frame Period; 4.27 or 8.53 seconds (525-line/60 HZ) 5.12 or 10.24 seconds (625-line/50 Hz) Output Signal Characteristics The output signal characteristics are: Type: Baseband, narrow-band video formatted. Level: Can be adjusted using front panel OUTPUT LEVEL control up to 6 volts p--p when connected to a 600 ohm transmission line. Connect oscilloscope to TP2 to monitor output signal level. Spectrum: DC to 15 KHz. Maximum energy at 60 Hz (50 Hz for 625-line TV source) and multiples thereof. Typical Systems Responses Frequency Response: 11 to 15 khz Signal-to-Noise Ratio: 60 db or better Attenuation: 20 db max

Detailed Description Paragraph Table (3):

UPCONVERTER INPUT Frequency 70 .+-.20 MHz Level -30 dBm .+-.4 (75 ohm) Bandwidth 40 MHz (IF) OUTPUT Frequency 14.0-14.5 GHz Power (2 W Power Amp) +33 dBm @ 1 dB comp. Spurious -60 dBc at rated power AM/PM Conversion 3.degree./dB at rated power Intercept Point +41 dBm VSWR 1.25 (50 ohm) DOWNCONVERTER INPUT Frequency 11.7-12.2 GHz Level -80 to -127 dBm System Noise Figure 2.7 dB (250.degree. K.) VSWR 1.2 (50 ohm) OUTPUT Frequency 70 MHz .+-.20 MHz IF Bandwidth 40 MHz Intercept Point +22 dBm VSWR 1.5 (75 ohm) Spurious Out -85 dBm GAIN Gain 85 dB .+-.3 dB @ 25.degree. C. with 30 dB manual attenuation Gain Flatness .+-..5 dB/40 MHz Gain Stability .+-.2.5 dB over temperature range

Detailed Description Paragraph Table (4):

SPECIFICATIONS

Size: Main Chassis 31/2" .times. 17" .times. 13" Single Memory Table Top 51/4" .times. 19" Multiple Memory Rack Mount Remote Control 8" .times. 6" .times. 21/2" Weight: 15 lbs. Single Memory Construction: Solid state, card file Power: 117 VAC, 60 Hertz, single phase, 75 VA Inputs: Receive: Slow-scan video: FM modulated carrier, 100 millivolts minimum level, 600 ohms, balanced Transmit: Composite video: 1 volt, 75 ohms, 2:1 interlace (3 inputs) Outputs: Receive & Transmit: Composite video: 1 volt p--p, 75 ohms, 2;1 interlace Transmit: FM modulated carrier, 1500 to 2400 Hertz, 0 to 2 volts p--p internally

adjustable, 600 ohms, balanced Controls: Remote Control: Fast/Slow Rate Video Source: 1-2-3 Transmit Start Freeze Reset Receive Start Multiple Memory Unit Only: Write: 1/2/or more Display: 1/2/or more Main Chassis: AC Power Single/Continuous Transmission Video Level Black level Indicators: Scan Black Level White Level Connectors: BNC-Video 5 Pin Amphenol - Transmission Line 14 Pin Blue Ribbon - Remote Control Performance: Resolution: Slow speed: 256 .times. 256 picture elements; TV test chart resolution is 270 lines Fast speed: 256 .times. 256 picture elements; repeats same data in both fields; TV test chart resolution is 135 lines Option: 512 .times. 512 picture elements, dot interlace Frame Time: 74 seconds for full resolution 34 seconds for medium resolution 148 seconds for high resolution option Grayscale: 6 bits (64 gray levels) Option: 8 bits Options: Receive Only Transmit Only Frame Freeze Only Multiple Memories

Detailed Description Paragraph Table (5):

CONTROLS Use

Control Function Transmit Receive

Operating Controls - Chasis Power ON/OFF switch with X X internal pilot light to indicate when unit is on. Black Level Controls the DC level of X the video signal going to the internal A/D converter. Usually set so that detail in the black portions of the input signal are not lost. Video Level Controls the amplitude of X the video signal going to the internal A/D converter. Usually set so that white details of the input signal are not compressed. Single/Cont SINGLE position requires X the operator to manually initiate the transmission of each frame. CONT position causes the 290 to automatically refreeze and scan with an interval of one second between scans. Fast/Slow When set in the FAST X X position, the 290 transmits or receives a singlefield picture in 34 seconds. When set in the SLOW position, a fullframe picture is transmitted in 74 seconds. Source: Selects the video input X signal sent to the freeze circuitry. Position 1 selects VIDEO IN 1, etc. Freeze Momentary pushbutton that initiates the A/D conversion and storage of one frame of video from the selected source. When this pushbutton is held down, a continuous real-time display of the selected input signal will be displayed on a monitor connected to the VIDEO OUT connector. Transmit Momentary pushbutton that X Start starts the transmission (scan) process when the SINGLE/CONT switch is in the SINGLE position. Reset Momentary pushbutton that X X terminates the transmission or reception. Receive Momentary pushbuttom that X Start starts the receive process if for some reason the start burst was missed.

Control

Location Function Transmit Receive

Line/Gen/ Sync & Selects the synchronizing X X XTAL Timing BD source for the internal sync generator. In the LINE posi- tion, the 290 timing is synch- ronized to the power line fre- quency. In the GEN position, the timing is synchronized (genlocked) to the sync information of the selected video input. In the XTAL position, the timing is synchronized to a crystal running at a multiple of NTSC color subcarrier frequency. Any unit to be used as a trans- mitter, should be set to GEN. Any unit that will be used only receiver, should be set to LINE. Color receivers should be set to XTAL.

Control

Location Function

Internal Controls Input Level 1 KHz FM Sets the amplitude of the FM Receive BD signal into the FM demodulator. Set at the factory for normal phone line levels. Symmetry 1 KHz Sets the DC level at which the Receive BD incoming FM signal is sliced. Set at the factory for normal phone line response. Improper adjustment is indicated by a granular "woodgrain" pattern in the received picture. Black Level 1 KHz FM Sets the DC level of the demodulated Receive BD input signal at the input to the A/D converter. Set at factory so the BLACK indicator light blinks when full blacks are present in incoming signal. Gain 1 KHz FM Sets the amplitude of the demodulated Receive BD input signal at the input to the A/D converter. Set a factory so that WHITE indicator light blinks occasionally on peak white signals. Delay 1 KHz FM Sets the window for A/D conversion Receive BD to correspond with the sample time. Set at factory. Start Burst 1 KHz FM Sets the capture frequency of the Frequency Receive BD start burst detector. Set at factory 787 Hz. Black Level 1 KHz FM Sets the frequency transmitted as Frequency Transmit BD black in the FM output signal. Set at factory for 1800 HZ. Deviation 1 KHz FM Sets the frequency transmitted as Transmit BD white in the FM output signal. Set at factory for 2500 Hz. Output 1 KHz FM Sets the amplitude of the FM output. Level Transmit BD signal. Set at factory for 2 V p--p into 600 ohms. Line Sync 1 KHz FM Sets the amplitude of the Line Sync Amplitude

Transmit BD pulse. Set at factory for 1:2 ratio of sync to video. Lock Adj. Sync & Sets the gen lock to middle of Timing BD range. Horizontal Sync & Determines the location of the Timing BD left side of the raster in the video output display. Normally set to EI RS-170. Output Memory & Controls the amplitude of the video Display BD portion of the video output signal. Offset Memory & Controls the black level of the video Display BD portion of the video output signal.

Detailed Description Paragraph Table (6):
CONTROLS
Control Function
Operating Controls (Front Panel) Power ON/OFF switch with internal pilot light to indicate when unit is on. Black Level Controls the DC level of the video signal going to the internal A/D converter. Usually set so that detail in the black portions of the input signal are not lost. Video Level Controls the amplitude of the video signal going to the internal A/D converter. Usually set so that white details of the input signal are not compressed. Store Pushbutton switch. The input video is being A/D converted and stored continuously as long as this push- button is depressed. Upon release of the button, the 491 stores the next frame. Control Location Function
Operating Controls (Internal) Lock Sync, Timing, Sets the line-sync lock to the & A/D Board middle of its lock-in range. H Width Sync, Timing, Determines the location of the & A/D Board left side of the raster in the video output display. Clock Sync. Timing, Sets master timing clock & A/D Board control loop to middle of control range. Amplitude Memory Board Controls the amplitude of the video portion of the video output signal. Pedestal Memory Board Sets the black level setup above blanking. Sync. Memory Board Sets Sync level in output video. SPECIFICATIONS Weight: 16 lbs. (20 lbs. for 51/4" chassis) Mounting: Standard 19" rack Construction: Solid-state, card file Power: 117 VAC, 70 Hertz, single phase, 100 VA (100 VAC, 230 VAC, and 625-line/50 Hz. optional) Inputs/Video: Composite video; 1 V p--p, 75 ohms Inputs/Digital: Store: Pulse, ground true, 1 microsec. min. (Memory select on multi-memory configurations) Outputs/Video: Composite, 1 V p--p, 75 ohms Controls: AC Power: On/Off Store (can be remoted) Video Level Black Level Indicators; Power Performance: Resolution: 512 .times. 512 picture ele- ments, dot interlaced; TV test chart resolution is 400 lines. Frame Time: Grab: 33 msec. (Computer access: 1 Sec. with optional 793 I/O Module) Grayscale: Standard: 8 bits (256 level) Options: 1 to 7 bits Conversion .+-.0.2%; .+-.1/2 LSB Linearity: Video 5 MHz Band width:

L19: Entry 59 of 63 File: USPT Jul 13, 1993

DOCUMENT-IDENTIFIER: US 5227797 A
TITLE: Radar tomography

Abstract Text (1):
A radar tomography method and apparatus usable in industrial applications emits a plurality of radar pulses toward an adjacent object. A transmitter provides the plurality of radar pulses to the antenna, and a receiver receives the plurality of reflected radar pulses which correspond to the emitted plurality of radar pulses reflected from internal structure within the object. Timer/gate means selects predetermined radar pulses from among the received radar pulses, the selected radar pulses corresponding to a predetermined area of interest within the object. The selected radar pulses include pulses which represent internal structure of interest and pulses which represent internal structure which is contiguous to the internal structure of interest. The selected pulses include information which discriminates the internal structure of interest from the contiguous internal structure.

Brief Summary Text (3):
A variety of medical imaging modalities are known and include nuclear magnetic resonance, ultra-sound, sonography, positron emission, digital subtraction angiography, and x-rays. Computed tomography is a well-known method for manipulating data to produce medical images. For example, ultra-sound, positron emission, and X-rays may utilize computed tomography techniques to produce images for diagnosis. A recent article, "III Imaging With Photons", by Edward Rubenstein, appearing in the December, 1988, edition of CURRENT TRENDS IN MEDICINE, explains several of these imaging methods and is incorporated herein by reference.

Brief Summary Text (4):
However, all known medical imaging modalities are considered to be either too expensive or may be at least somewhat harmful to the patient. For example, a nuclear magnetic resonance machine may cost $2.5 million and require almost one-thousand dollars to produce an image. On the other hand, the use of X-rays is disadvantageous in that repeated use may result in harm to the patient.

Brief Summary Text (5):
Furthermore, known imaging techniques can create an image by passing energy through the patient to produce a projected image or a cross-sectional image of the patient. The power required to pass certain types of energy and energized particles through a patient is expensive to produce and may cause harm to patient tissue.

Brief Summary Text (8):
It is known that radio waves will penetrate human tissue, and that radio wavelengths of electromagnetic radiation are considered non-ionizing, thus causing no radiation damage. For example, current technologies employ short-wave and microwave radiation to treat deep muscle injury with controlled heat. No tissue damage occurs even when the radio waves are applied steadily for periods of up to 30 minutes. U.S. Food and Drug Administration (FDA) guidelines for use of such modalities are currently available. Furthermore, radar technology is relatively well developed in military and civilian aviation. In addition, the proliferation of radar guns and related equipment in traffic enforcement is well-known.

Brief Summary Text (9):
Radar uses a wavelength of several meters to several millimeters. Radar can also be focused into more concentrated beams than X-rays. In addition, sensitive radar receivers are available which can image an object at great distances registering a small fraction of the radiated energy. Radar also produces an image by reflecting

energy from an object, thus requiring less power and producing less tissue damage in the patient than known techniques. Thus, it appears that radar signals may be useful in medical imaging.

Brief Summary Text (12):
In order to achieve the above object, the present invention is directed to a method and apparatus for emitting a plurality of radar or radio pulses toward a subject with an antenna, providing the radar pulses to the antenna with a transmitter, and receiving the plurality of radar pulses reflected from the subject with a receiver. A timer/gate circuit is used to select predetermined radar pulses from among the received, reflected radar pulses. The radio pulses selected are those which correspond to a predetermined area, at a predetermined depth, of interest within the subject.

Brief Summary Text (14):
If desired, a three-dimensional image of a predetermined volume within the subject can be produced by generating relative movement between the antenna and the subject. This produces a sequence of scans at differing depths within the target volume within the patient. A processor then stores and manipulates the view data in order to produce a three-dimensional view of the predetermined volume within the subject.

Brief Summary Text (15):
In order to more accurately focus the emitted and reflected radar pulses, the present invention may include a matrix filter, coupled to the antenna, which reduces noise by eliminating unwanted reflection and diffraction components. The matrix filter may include a plurality of radar absorbing tubes disposed to form a grid in cross-section.

Detailed Description Text (2):
The principle of radar is relatively simple. Radio wave energy is emitted toward an object and its position and relative movement may be determined through the return radio echo. The frequency of the radio pulses and the intensity of each pulse may be varied in accordance with the type of echo desired, the relative distance to and movement of the subject, and the type of antenna used. From the return echo, the distance to the object may be readily calculated by well-known Doppler techniques. The signal-to-noise (SNR) ratio of the return echo pulses may be diminished by resonance, diffraction, or off-phase interference. Techniques for reducing resonance (artificial wave amplification), and off-phase interference are well-known and could be implemented in the present invention.

Detailed Description Text (3):
Diffraction may reduce the SNR by causing scattering of the return pulses into the receiver. As will be discussed below, the present invention proposes a matrix filter in order to reduce diffraction noise.

Detailed Description Text (4):
Producing a medical image from the return echo pulses can be a matter of applying existing technology. Well-known computed tomography techniques may be used to process the return radar signals in order to produce usable images for medical diagnosis. For example, a timer/gate device may be used to gate the receiver so that it receives only pulses from a selected distance. Another technique is to utilize a so-called range filter in which a plurality of range bins are disposed. A return radar signal entering a particular range bin indicates that the subject is at a predetermined distance from the antenna. Such techniques are known in the radar field and need not be described in greater detail herein.

Detailed Description Text (6):
In FIG. 1, the patient or subject 2 is exposed to pulsed radio signals 4 emitted from an antenna head 6. As schematically shown there, antenna head 6 includes an antenna 8, an aperture control device 10, a matrix filter 12, and a cone or cylinder spacer 14. A standard dental X-ray cone is usually 8 or 18 inches long, and therefore, an 18 inch cone or cylinder spacer 14 would be quite normal for use with the patient and by medical personnel. In addition, an 18 inch spacer 14 would provide approximately a 1 meter path for rays emitted from the antenna and reflected from the subject.

Detailed Description Text (7):
Antenna 8 may comprise any well-known or conventional radar antenna. For example, parabolic, Cassegrain, dipole, or flat semi-conductor antennas may be used. The

antenna should be simple, light-weight, and inexpensive. The antenna should also be small enough to fit into the antenna head 6 and allow for ease of operation by medical personnel.

Detailed Description Text (8):
The aperture control device 10 is used to control the aperture of the antenna 8. This device 10 may include synthetic aperture control circuitry, or mechanical means such as two plates of radar-absorbing materials with slits moving in opposite directions allowing synchronous radiation emission and reception through one aperture at a time. Additionally, while the aperture control 10 is shown located between the antenna 8 and the filter 12, it may be located between the filter 12 and the patient 2. Again, such aperture control devices are relatively well-developed and need not be described in further detail here.

Detailed Description Text (10):
A duplexer 16 is provided to switch the antenna between a transmitting mode and a receiving mode. In the absence of the duplexer, the transmitted energy may harm a receiver 22 connected therethrough to receive the reflected radiation. Again, duplexers are very well known and are readily available. Of course, two antennae (one for transmitting, one for receiving) may be used in the present invention, thus eliminating the need for a duplexer.

Detailed Description Text (11):
A transmitter 18, also connected to the dupluxer 16, is a high-power oscillator which generates the radar pulses at a predetermined frequency, amplitude, and phase. A modulator 20 provides pulses of input power to activate the transmitter 18. For the duration of the input pulse from the modulator 20, the transmitter 18 generates a high-power radio frequency wave, converting a DC pulse to a pulse of radio frequency energy. The exact frequency of the emitted energy may be tuned to any appropriate range, as desired. The generated radio wave pulses are then transmitted to the antenna 8 through the duplexer 16.

Detailed Description Text (12):
The receiver 22 receives the reflected radar pulses from the antenna 8 through the duplexer 16. Typically, the receiver 22 is a superheterodyne receiver which translates the received signals from their frequency to a lower, intermediate frequency at which they can be filtered and amplified more conveniently. Translation is usually accomplished by adding the received signals to the output of a low-power local oscillator in a mixer. The output of the mixer is usually amplified and then filtered to reduce interfering signals, electrical background noise, resonance, and off-phase interference noise. Finally, the amplified received signals are output to a video processor 26 through a timer/gate 24 discussed below in detail. Radar receivers as described above are well known and need not be explained in further detail.

Detailed Description Text (13):
The timer/gate 24 is a device which selects predetermined pulses from among the received pulses in order to effect spatial control. For example, as the radar pulses are reflected back from the lower jaw of the patient 2, the timer/gate 24 selects only those return pulses timed to return from a desired depth (for example, 2 centimeters from the forward edge of radar head 6). Accordingly, only the gated pulses would be accepted for imaging. Preferably, timer/gate 24 controls the receiver 22 so that it only receives radar pulses from the desired location. By varying the return-plane distance within the patient by moving the antenna head toward or away from the volume of the patient under study, or by varying the time of acceptable pulse return, readings can be obtained for any desired tissue depth within the patent 2. The timer/gate 24 must be very sensitive since the patient 2 will be positioned close to the radar head 6. Timers capable of measuring picoseconds are now known. For example, such a timer identified by Model No. DG-535 is available from Stanford Research.

Detailed Description Text (17):
A high-resolution image of the area or volume of interest may also be obtained by providing relative movement between the antenna head 6 and subject 2. Thus, the movement control device 34 may be coupled to the antenna head 6 to move it with respect to patent 2. In a manner similar to a CATSCAN, the antenna head 6 may be moved in an arc around subject 2 in order to take several "shots" or "views" of the subject 2. In each view, the radar pulses are scanned in the X and Y directions by use of the aperture control 10, and in the depth direction by using the timer/gate

24. When information regarding the plurality of "views" is combined, a higher resolution image of the volume of interest may be obtained. Those having skill in this field will understand that the principles of image processing used in a CATSCAN device can be adapted to the present radar tomography device.

Detailed Description Text (18):
The signal output from the video processor 26 is an analog video signal capable of being stored on the video storage device 26 (for example, a VCR), or displayed on the video display device 30. However, digital techniques offer significant opportunities for image enhancement. Therefore, the analog signal from the video processor 26 may be provided to an analog-to-digital converter 36 to digitize the signal. The digitized signal is then provided to a digital processor 38 which can manipulate the data in a variety of well-known ways. For example, information from a plurality of "views", as discussed above, may be combined within the processor 38 to produce a high-resolution, three-color, three-dimensional view of a volume of interest within subject 2. Such images may then be converted to an analog signal by a digital-to-analog device 42 for display on the video display 30. The digital output from the processor 38 may also be provided to a memory 40 which stores the information for later retrieval and use. Imaging processors such as those used in nuclear magnetic resonance imaging may be adapted for use in the present invention.

Detailed Description Text (19):
FIG. 2 is a perspective view of a preferred embodiment of the matrix filter 12. The matrix filter 12 has the dual function of focusing the emitted radar energy on the area of interest and eliminating diffraction noise from the reflected return pulses. Diffraction caused by scattering of the return waves is avoided by the size of the matrix filter 12. Matrix filter 12 is preferably a radar-absorbing 10 centimeter square parallel filtering box, broken into a cross-sectional grid of square tubes. The grid comprises a plurality of perpendicularly disposed radar-absorbing panels 121. The number and spacing of the panels may be modified somewhat, depending upon the desired radar frequency, phase, and power. Alternatively, the filter may be made of a matrix of parallel cylindrical tubes of radar-absorbing materials. Of course, the tubes may be of other cross-sectional shapes. Again, the design of such filters is fairly well developed in the radar field.

Detailed Description Text (20):
Thus, what has been described is a medical imaging modality using radar-frequency signals to produce inexpensive, high-resolution images of a subject. The apparatus utilizes existing technology, and therefore, should be relatively inexpensive to manufacture, market, and operate. Furthermore, medical insurers and patients alike will welcome such a safe, low-cost alternative to X-rays and nuclear magnetic resonance.

CLAIMS:

1. A radar tomography apparatus, comprising:

antenna means for emitting a plurality of radar pulses toward an adjacent object;

transmitting means for providing the plurality of radar pulses to said antenna means;

receiver means for receiving a plurality of reflected radar pulses which correspond to the emitted plurality of radar pulses reflected from internal structures within the object;

timer/gate means for selecting predetermined radar pulses from among the received radar pulses, the selected radar pulses corresponding to a predetermined area of interest within the object, the selected pulses including pulses which represent internal structure of interest and pulses which represent internal structure which is contiguous to the internal structure of interest, the selected pulses including information which discriminates the internal structure of interest from the contiguous internal structure.

6. Apparatus according to claim 1, further including a matrix filter, coupled to said antenna means, for directing both the emitted radar pulses and the reflected radar pulses.

7. Apparatus according to claim 1, wherein said antenna means comprises:

a spacer head;

an antenna coupled to said spacer head;

an aperture control device for controlling an aperture of said antenna; and

a duplexer for switching said antenna between said transmitter means and said receiver means.

8. Apparatus according to claim 7, further including a matrix filter, coupled to said antenna, for directing the emitted radar pulses and the reflected radar pulses.

9. Apparatus according to claim 1, wherein said transmitter means comprises:

a transmitter for generating a plurality of generated radar pulses;

a modulator for modulating the generated radar pulses to produce the plurality of radar pulses provided to said antenna means; and

a synch processor for controlling the modulator to produce the plurality of radar pulses at predetermined timings.

11. Radar tomography apparatus, comprising:

an antenna for emitting a plurality of radar pulses toward an object, and for receiving a plurality of reflected radar pulses reflected from internal features within the object;

a filter for guiding the emitted and reflected pulses toward and from the object, respectively;

a transmitter for providing the plurality of radar pulses to said antenna;

a receiver for receiving the plurality of reflected radar pulses from said antenna;

a timer/gate circuit for selecting predetermined ones of the reflected radar pulses received by said receiver, the selected radar pulses corresponding to a predetermined area within the object, the selected pulses representing both internal structure of interest and internal structure contiguous to the structure of interest, the selected pulses discriminating between the internal structure of interest and the contiguous internal structure; and

display circuitry for receiving the selected radar pulses from said timer/gate circuit and displaying a representation of the predetermined area within the object.

12. Apparatus according to claim 11, further comprising an aperture control device for controlling an aperture of said antenna.

16. Apparatus according to claim 11, further comprising movement means for producing relative movement between said antenna and the object, and wherein said receiver receives a plurality of sets of reflected radar pulses, and wherein said timer/gate circuit selects radar pulses from among each set, the selected pulses corresponding to a predetermined volume within the object.

17. Radar tomography apparatus, comprising:

an antenna for emitting a plurality of radar pulses toward an object, and for receiving a plurality of reflected radar pulses reflected from internal features within the object;

a filter, disposed between said antenna and the subject, for filtering the emitted and reflected radar pulses;

a duplexer for switching said antenna between a transmit mode and a receive mode;

a transmitter for providing the radar pulses to said antenna;

a receiver for receiving the reflected radar pulses from said antenna;

a timer/gate circuit for controlling said receiver to cause only radar pulses reflected from a predetermined area within the object to be received, the selected pulses representing both internal structure of interest and internal structure contiguous to the structure of interest, the selected pulses discriminating between the internal structure of interest and the contiguous internal structure; and

a processor for controlling said timer/gate circuit to cause said predetermined area to be scanned to different locations within the object.

19. Apparatus according to claim 17, further comprising movement means for producing relative movement between said antenna and the object, and wherein said transmitter provides a plurality of sets of radar pulses to said antenna, each set being emitted at a different position, and wherein said timer/gate circuit causes said receiver to receive only radar pulses reflected from a predetermined volume within the object.

21. Radar tomography method, comprising the steps of:

emitting a plurality of radar pulses toward an object, using an antenna;

providing the plurality of radar pulses to said antenna;

receiving a plurality of reflected radar pulses which correspond to the emitted plurality of radar pulses reflected from internal structure within the object; and

selecting predetermined radar pulses from among the received radar pulses, the selected radar pulses corresponding to a predetermined area within the object, the selected pulses representing both internal structure of interest and internal structure contiguous to the structure of interest, the selected pulses discriminating between the internal structure of interest and the contiguous internal structure.

27. A method according to claim 21, wherein said emitting step includes the step of:

controlling an aperture of said antenna; and

switching said antenna from a receive mode to a transmit mode.

29. A method according to claim 21, wherein said emitting step comprises the steps of:

generating a plurality of generated radar pulses;

modulating the generated radar pulses to produce the plurality of radar pulses provided to said antenna; and

controlling the modulator to produce the plurality of radar pulses at predetermined timings.

31. Radar tomography method, comprising the steps of:

emitting a plurality of radar pulses toward an object, and for receiving a plurality of reflected radar pulses reflected from internal features within the object, using an antenna;

guiding the emitted and reflected pulses toward and from the object, respectively, using a filter;

providing the plurality of radar pulses to said antenna;

receiving the plurality of reflected radar pulses from said antenna, using a receiver;

selecting predetermined ones of the reflected radar pulses received by said receiver, the selected radar pulses corresponding to a predetermined area within the object, the selected pulses representing both internal structure of interest and

internal structure contiguous to the structure of interest, the selected pulses discriminating between the internal structure of interest and the contiguous internal structure; and

displaying a representation of the predetermined area within the object, based on the selected radar pulses.

32. A method according to claim 31, further comprising the step of controlling an aperture of said antenna.

34. Apparatus according to claim 31, further comprising the step of producing relative movement between said antenna and the object, and wherein said receiving step includes the step of receiving a plurality of sets of reflected radar pulses, and wherein said selecting step includes the step of selecting radar pulses from among each set, the selected pulses corresponding to a predetermined volume within the object.

35. Radar tomography method, comprising the steps of:

emitting a plurality of radar pulses toward an object, and receiving a plurality of reflected radar pulses reflected from internal structure within the object, using an antenna;

filtering the emitted and reflected radar pulses;

switching said antenna between a transmit mode and a receive mode;

providing the radar pulses to said antenna;

receiving the reflected radar pulses from said antenna, using a receiver;

controlling said receiver to cause only radar pulses reflected from a predetermined area within the object to be received, the selected pulses representing both internal structure of interest and internal structure contiguous to the structure of interest, the selected pulses discriminating between the internal structure of interest and the contiguous internal structure; and

causing said predetermined area to be scanned to different locations within the object.

37. A method according to claim 36, further comprising the step of producing relative movement between said antenna and the object, and wherein said emitting step emits a plurality of sets of radar pulses, each set being emitted at a different position, and wherein said controlling step causes said receiver to receive only radar pulses reflected from a predetermined volume within the object.

DOCUMENT-IDENTIFIER: US 6221094 B1
TITLE: Resonant frequency therapy device

Abstract Text (1):
A generator of a complex energy wave, having audio, radio and light components, including an audio frequency oscillator, a radio frequency transmitter, a radio frequency amplifier, an antenna tuner, an antenna, tuned coaxial cables and an optional reverberation unit.

Brief Summary Text (5):
Organisms are able to absorb or store energy which later may be converted into useful work, heat or re-radiated. In the event energy is absorbed faster than the subject may utilize it, or re-radiate it, excess energy builds up. When an organism is under the influence of an energy wave having frequency equal to the resonant frequency of the organism, the organism, or at least some resonant part of it, continues absorbing energy. At the point where too much energy is absorbed, the energy begins to cause failure in the structure absorbing the energy. At resonance, this process of structural failure occurs very quickly. This may easily be seen by exposing Paramecium Caudatum to the present device when operating at 1150 Hertz (Hz). The normally very motile organism literally stops motion while changes occur in the protoplasm until a point in the cell wall fails.

Brief Summary Text (6):
The energy associated with this process is described by the formula, E=hv, which is applicable to ultraviolet light, X-rays, and radiation on various molecules. "E" symbolizes energy content, "h" represents Planck's constant and "v" stands for the frequency in cycles per second.

Brief Summary Text (7):
Electromagnetic waves include visible light, heat, X-rays, radio waves and the like. These are all merely different frequencies of the electromagnetic spectrum, and as such have different properties. Each may be amplified, diminished, changed in frequency, radiated or even heterodyned. Heterodyning is the combining of two dissimilar waves to produce two new waves. One of the new waves is the sum of the two frequencies, the other new wave being the difference of the frequencies.

Brief Summary Text (8):
The use of audio, radio and light waves to treat diseased tissue is well known in the arts. Audio wave-type devices typically employ a piezoelectric ultrasonic generator driven by a radio frequency amplifier coupled to an ultrasonic lens of known focal length. The locus of cells to be destroyed is ascertained through known pulse-echo imaging techniques. Once the locus of target cells is fixed, the lens is focused on the target area and the intensity of the ultrasound is increased to a level sufficient to affect tissue destruction by thermal heating. An example of this technique is shown in U.S. Pat. No. 4,315,514, issued Feb. 16, 1992, to William Drews et al.

Brief Summary Text (9):
Radio wave-type cell destroying devices typically employ amplitude-modulating transmitters in series with an amplifier, tuner and antenna for training high power radio waves on a target area. As with the above device, the intensity of the radio waves increases to a level sufficient to affect tissue destruction by thermal heating.

Brief Summary Text (10):

Light wave-type cell destructive devices typically employ lasers, constructed by known means, which also are trained only a target locus of cells. The high intensity light waves deliver light energy of an intensity sufficient to affect destruction of the cells by a thermal heating.

Brief Summary Text (13):
Each of the above devices have been somewhat effective in destroying living cells, but, individually, are not fully compatible with the complex nature of living cell tissue. As a testament to this, some analytical tools have been developed which simultaneously apply different kinds of wave energy. For example, in U.S. Pat. No. 5,402,782, issued Apr. 4, 1995, and U.S. Pat. No. 5,553,610, issued Sep. 10, 1996, both to Robert A. Lodder, similar devices are disclosed which simultaneously apply to a subject, a magnetic field, near-infrared radiation and an acoustic wave. Collection of the electrical, acoustical and near-infrared spectra provides much more comprehensive data that is more useful in the treatment of the subject.

Brief Summary Text (14):
Although multi-component wave generating devices have been used for analytical purposes, none are used for affecting cell destruction. Owing to the complex nature of biological cells, a need exists for a resonant frequency therapy device providing for the transmission of multiple wave energies.

Brief Summary Text (17):
The present invention overcomes the limitations of the above inventions by providing a resonant frequency therapy device which delivers a complex transmission of energy waves comprising audio, radio and light waves, possibly generating a fourth type of wave. The invention includes known components, namely an audio frequency oscillator, a radio frequency transmitter, a radio frequency amplifier, an antenna tuner, an antenna, tuned coaxial cables and an optional reverberation unit.

Brief Summary Text (18):
This is a new method of application of therapeutic electrical waves. This method relies upon shaping an overmodulated radio wave pulse in a radio transmitter and then outputting that pulse into a gas filled tube. The gas within the tube is then excited by the overmodulated radio energy, and the wave form output from the gas filled tube will penetrate and couple to all tissues in the patient producing physiologic effects based upon the applied audio frequency.

Brief Summary Text (20):
A second object of the invention is to provide a resonant frequency therapy device which may be constructed from inexpensive readily available materials.

Brief Summary Text (21):
A third object of the invention is to provide a resonant frequency therapy device which combines diverse wave energies and generates a composite energy wave which may be used to treat malignant cells.

Drawing Description Text (3):
FIG. 2 is a diagrammatic view of an embodiment of an antenna used with the invention.

Drawing Description Text (4):
FIG. 3 is a diagrammatic view of an embodiment of an antenna used with the invention.

Drawing Description Text (5):
FIG. 4 is a diagrammatic view of an alternative embodiment of an antenna used with the invention.

Drawing Description Text (6):
FIG. 5 is a diagrammatic view of an alternative embodiment of an antenna used with the invention.

Detailed Description Text (2):
The present device incorporates a phenomenon known as harmonics in its operation to trigger the resonant characteristics of target cells or organisms. A harmonic is a multiple of the original (fundamental) frequencies of wave functions. For example, a second harmonic of 100 cycles is 200 cycles or Hz while a third harmonic would be 300 cycles.

Detailed Description Text (3):
The invention employs square shaped wave functions which are made up of an infinite number of the odd numbered harmonics fundamental frequency. That is, a square wave is constructed from sine waves using the third, fifth, seventh and so on, harmonics of the fundamental frequencies. For example, a 1000 cycle fundamental output square wave contains sine waves of 3000 Hz, 5000 Hz, 7000 Hz, and all other odd numbered harmonics.

Detailed Description Text (4):
The invention employs an amplitude modulated (AM) radio wave which comprises three waves, the primary wave and two side bands which are the sum and difference of the radio wave and the modulated audio wave. For example, a 1000 cycle audio wave on a 1,000,000 cycle radio wave produces two side bands; one, the lower side band at 999,000 cycles, and two, the upper side band at 1,001,000 cycles. The separation between the upper and lower side bands is what is known as the bandwidth. In this example, the bandwidth is 2000 cycles. The harmonics that make up the audio frequency square wave will produce the bandwidth of the transmitted electromagnetic wave, which will play an important part in the construction and operation of the present invention.

Detailed Description Text (5):
The side bands are important in that they contain all of the square waves generated. The side bands contain only one third of the power of the total electromagnetic energy generated and transmitted, while the carrier wave retains the other two thirds of the power transmitted. All of the harmonics that make up the square wave also will produce side bands of their own. Further, a linear amplifier will produce harmonics of the primary input radio wave generated by the transmitter used in the present invention. These harmonics of the radio wave also will act as a carrier of all the harmonics of the square wave and produce another set of side bands, thus resulting in literally hundreds of radio and audio frequencies produced by and introduced into a plasma tube antenna, discussed below. The effects of the device are dependent upon the properly applied audio frequency. It is the audio frequency that determines the formation of side bands, and the ability to produce resonant interaction between the device and the selected tissues or microorganisms. Therefore with the proper audio frequency resonant effects occur, and with the incorrect audio frequency, there are no effects.

Detailed Description Text (6):
Referring to FIG. 1, the device includes a low power radio frequency transmitter 10 generating radio waves having a radio frequency and a radio function. The radio frequency utilized generally is in the 2 to 33 MHZ range. It has been found that certain radio frequencies may produce deeper tissue penetration with the device than other radio frequencies. The radio frequency used to excite the plasma may of course be varied as necessary to achieve optimal effects. The FCC has set aside certain frequencies for use with industrial, scientific and medical (ISM) devices. The most commonly used of these is located at 27.12 MHZ. The allocated bandwidth by the FCC at 27.12 MHZ is + or -163,000 cycles or a total of 326,000 cycles. It is to the devices advantage to utilize all this available allocated bandwidth in its operation.

Detailed Description Text (7):
The primary low power radio frequency transmitter must be Amplitude Modulated preferably on a frequency of 27.12 MHZ. The simplest method to generate the necessary 27.12 AM radio wave is to utilize a standard Citizen Band (CB) radio set to operate on channel 14. CB radios generally include audio filters that limit the audio frequency response to a range of 300 to 2500 cycles. This frequency limitation effectively inhibits and clips off the harmonics in the square wave. To overcome this frequency limitation, modifications are made to the CB radio that widens its bandwidth. Further, the modulation limiter of the CB radio is bypassed allowing the CB radio to over-modulate. Over-modulation produces a pulsed radio wave.

Detailed Description Text (8):
This pulse will of course have a positive and negative aspect. But once in the patients body the wave will demodulate, normally passing only the positive half of the wave into the tissues. By carefully shaping the overmodulated radio energy pulse, the radio energy pulse can be made to resemble the input wave form. When the wave demodulates within the tissues, the wave will once again be present in it's applied shape.

Detailed Description Text (9):
The limitation of this method is that the modulated frequency and the power of the radio energy must be of sufficient intensity to fully penetrate and permeate the tissues. Too little radio energy power, will cause a lack of penetration. Too little audio energy on the carrier wave will cause a lack of permeation or saturation of the tissues with the therapeutic audio wave. It has been found as a rule of thumb, that providing the audio is fully modulated, about one watt of RF power per pound of body weight is necessary for full penetration and optimum effects. The advantage of this method is that one can bypass any of the resistance effects of electricity, and that all the harmonics forming the original shaped audio wave are allowed to pass into the body cells without inhibition or distortion.

Detailed Description Text (10):
When the radio wave is modulated with an audio signal, the audio wave will therefore be pulsed too. The effects of pulsed radio frequency energy on tissues is well known. The unique effect generated by the modified CB radio is that the pulse width and duration varies directly with the modulated audio frequency square wave. The higher the audio frequency modulated, the shorter and more frequent the output pulse of radio energy.

Detailed Description Text (11):
The duration of each pulse is dependent of the duty cycle of the input wave form, and the duty cycle of the radio wave pulse. Generally the two duty cycles should correspond closely. The radio pulse should always be longer in time than the modulated wave pulse. For example if a 1000 Hz audio square wave of 50% duty cycle is introduced to the radio, the total time between each square wave would be 1 millisecond, and the time the square wave would be on is but 0.5 ms. The radio pulse should correspond closely to the audio timing and in this example, this would be anywhere from about 0.52 ms to 0.62 ms in length. There is an optimum timing for the radio pulse length based upon the duty cycle of the applied modulated wave. Either too long or too short a radio pulse will diminish the physiologic effects of the therapeutic wave.

Detailed Description Text (13):
The RF duty cycle may exceed 90% at extremely low applied audio frequencies, that is below 200 Hz. As one approaches 20 Hz the radio duty cycle may approach or exceed 95%. This long RF duty cycle seems to optimize the output wave, but only at extremely low audio frequencies. Above 300 Hz, the audio and the Rf duty cycles generally are very closely matched in duration.

Detailed Description Text (14):
The audio wave may also be gated, it has been found that this generally is at a rate of from about 0.5 to 4 times a second. Presently, a close to optimal audio gate rate, seems to be about 0.75 seconds on and then 0.75 seconds off. Or one complete on-off cycle every 1.5 seconds. The gating of the audio wave creates a gate effect of the radio wave pulses, the number of radio pulses generated per gating sequence is dependent upon the applied audio frequency. If the audio frequency was 1,000 Hz then each full radio pulse would be 1 ms. With a 0.75 second on gate, 750 radio pulses would pass before the gate closed. Gating of a radio pulse is not new, but using the gate to control a shaped RF wave output to a plasma tube is a new application.

Detailed Description Text (15):
The invention also employs an audio frequency oscillator 12 generating audio waves having an audio frequency and an audio function. The audio frequency oscillator 12 must provide for square wave output and should be adjustable in multiple range steps for frequency. Preferably, the quality of the square wave is quite high, being less than 0.1% distorted.

Detailed Description Text (17):
One way to deliver optimum voltage output to the microphone is to listen to the output of the CB unit on another CB and set the output voltage to produce a clear signal. A second way is to set the output of the square wave generator to below 0.2 volt, then set the plasma tube antenna 16 to near maximum brightness by increasing or decreasing the voltage out of the frequency generator. Once set for one frequency, the voltage output should be correct for all audio frequencies. A third way is to employ a wide band oscilloscope to set the voltage output to the microphone at its optimum level.

Detailed Description Text (18):
Ideally, the radio frequency transmitter delivers a pulsed wide band width radio wave with a pulse rate and width varying with the applied audio frequency. Also, the radio frequency amplifier should deliver power in an amount that increases as the audio frequency increases.

Detailed Description Text (20):
One may also sweep the audio frequency from a starting to an ending point, or may waver the audio frequency back and forth across a set value. The rate at which the frequency changes within the swept or wavered sequence, has been shown to enhance effects. Generally this is about 0.5 to 6 seconds per Hz. If the frequency changes too fast, there is not sufficient time for the wave to create changes and effects are not optimal. If the frequency changes too slowly, the physiologic effect of the sweep is lost. The patients body will respond in a manner similar to using a set continuous frequency and then changing to a new frequency. The use of a sweep and waver has been used in other prior devices but not with a shaped wave output through a radio frequency excited gas plasma.

Detailed Description Text (21):
Where a high powered AM radio transmitter is used, the invention includes the use of a wide band width linear radio frequency amplifier. A wide bandwidth linear amplifier is necessary in order to properly amplify the side bands generated by the primary radio frequency generator. Preferably the linear radio frequency amplifier has no harmonic suppression and will generate its own radio frequency band harmonic signals. The linear amplifier receives and amplifies the output radio wave from the primary transmitter. From the amount of amplification produced by the linear amplifier, a power multiplication factor can be determined. This power multiplication factor in a 200 watt output linear amplifier being driven by a 4 watt output CB radio is equal to 50. The power multiplication factor is important in giving power to the side bands generated by the input audio square wave. For example, a harmonically generated side band of the fundamental square wave audio frequency may have only one-half watt of power as it leaves the CB radio. After passing through the linear amplifier this same side band now has 25 watts of power.

Detailed Description Text (22):
Between the radio frequency transmitter and the radio frequency amplifier, the invention employs a discrete length of coaxial wire 20. The length chosen is crucial in that the invention is most effective where transmission occurs with a minimum of standing wave ratio. Standing wave ratio is a measure of the power absorbed by the antenna relative to the power reflected back to the radio frequency amplifier. The ideal ratio is 1:1, however anything below 2:1 is good. A standing wave ratio that is too high will destroy the amplifier as well as the transmitter. Ideally, the cable length should be 18 feet or 1/2 wavelength long. The use of an 18 foot or 1/2 wavelength cable between the primary radio transmitter and the linear amplifier has been found to facilitate the creation of a gas plasma within the plasma tube.

Detailed Description Text (23):
The invention also includes an antenna tuner 22. The antenna tuner matches the output of the radio frequency amplifier to the plasma tube 16 to insure that the maximum power is transmitted to the tube. The tuner receives the output from the radio frequency amplifier and supplies it via the wire terminals of the antenna tuner to the antenna leads of the plasma tube.

Detailed Description Text (24):
In order for the antenna tuner to function, it must be set on the lowest inductance regardless of the type of tube or gas used. Once the plasma lights in the plasma antenna, the standing wave ratio will approach infinity briefly until the plasma begins absorbing the power. At that point, the tuner knobs may be used to bring the standing wave ratio to a minimum. If the plasma does not light, input to the transmitter should be ceased temporarily to prevent damage to the primary radio frequency transmitter and linear amplifier.

Detailed Description Text (25):
Optionally, the invention may employ an external balun 24, an impedance matching transformer used in some antenna tuners. The balun plays an important role in the full generation of the plasma waves of interest. A balun is rated by its ability to match dissimilar circuits. For example, a 4:1 balun will match a 75 ohm to a 300 ohm circuit. The size and type of balun has a direct effect on the strength and field

density of the wave produced by the device. It has been found that certain baluns containing a large toroid can produce local fields that are physically difficult to tolerate for more than a few minutes at a time.

Detailed Description Text (26):
The invention employs a second length of coaxial cable 26 interposed between the radio frequency amplifier and antenna tuner. Ideally, the cable should be 18 feet or 1/2 wavelength long. The use of said 18 foot or 1/2 wavelength long cable tends to orient the output wave from the plasma tube fore and aft rather than laterally relative to the plasma tube.

Detailed Description Text (28):
The antenna tuner delivers energy to the antenna via approximately four feet of antenna wire 28. The standing wave ratio should be maintained under 2:1 to prevent damage to the electronics.

Detailed Description Text (29):
The invention employs a plasma tube 16 as an antenna. The antenna 16 generates an output signal. A plasma tube antenna allows exposure of the entire subject, or a room full of subjects at one time.

Detailed Description Text (34):
One must also match the applied radio power to the size of tube. Heat is generated by the application of radio energy to the tube, and too small a diameter, too small a volume or length of tube will decrease effects of this method. One also risks melting and perforation of the glass envelope. The inventor on one notable development day, managed to destroy three tubes within a hour from too much power and heat.

Detailed Description Text (37):
It has been found that a mauve color of the plasma seems to produce overall the highest physiologic effects. One can create this color with mixtures of argon and neon gasses, or with pure argon gas. The color is partially derived from the gas pressure in the tube, the applied audio frequency and radio energy power, the volume of the tube, and the way the RF energy is introduced into the tube.

Detailed Description Text (40):
Visible light generally exists between 3950 and 7050 angstroms. Accordingly, Neon provides comparatively little visible strength yet it is the brightest of the noble gases in the visible region when excited by radio frequencies.

Detailed Description Text (42):
It is well known that a shorter wavelength, in Angstroms, will provide for a more powerful spectral wave. Between 100 and 1000 angstroms, the wave has enough power to produce photoionization of O.sub.2, O, N.sub.2, and N. Between 1000 and 3000 angstroms, the spectral wave has enough power to photodissociate O.sub.2 and O.sub.3. Generally, germicidal ultraviolet radiation occurs between 2200 and 2950 angstroms. The most effective transmission commonly used being 2537 angstroms.

Detailed Description Text (43):
Table III, below, lists the typical amount of germicidal energy necessary to destroy common microorganisms. Significantly, all of the gases of interest produce spectral lines far below the 2537 angstrom level. These spectral lines can be of use only if utilizing either quartz or more silicate glass for the plasma tube.

Detailed Description Text (44):
It is currently hypothesized that some of the reason for the physiologic effects noticed with gating of the audio wave may be due to a reverse EMF that the body creates. That is if one considers the tissues to have an inductance, then when the wave turns off, a reverse EMF is generated which has effects different from just using a continuous output of pulsed RF.

Detailed Description Text (45):
Recent testing with a Hall effects sensor seems to indicate the presence of bodily magnetic fields at certain applied audio frequencies within the devices field. It is hypothesized that this method of introducing shaped wave forms may be producing Nuclear Magnetic Resonance effects in the bodies tissues. Meaning that a new method of the generation of NMR may possibly be derived from the use of this method of application of waveforms.

Detailed Description Text (46):
In the use of MRI instruments which measure and correlate NMR in the body to produce internal pictures, the radio wave is varied in frequency, the magnetic field may be varied in intensity, and the pulse width is generally kept static. Most MRI units use an RF pulse width of around 20 ms.

Detailed Description Text (47):
In this invention, the RF pulse width varies with the applied audio frequency, but keeps the radio frequency fixed. However there is no reason that one could not vary the radio frequency keeping the audio frequency fixed, and thus the pulse width fixed, or one could also vary the audio frequency with the radio frequency. Which ever method or combination there of would be necessary to optimize effects. The LARMOR frequency of NMR is determined by the following equation:

Detailed Description Text (49):
v=frequency in cycles per second

Detailed Description Text (51):
y=the gyromagnetic ratio-26,750

Detailed Description Text (52):
If one considers the relatively weak magnetic field of the earth (about 0.5 gauss) or of the devices EMF as static, then using the above equation, it can be seen that NMR effects will occur at audio frequencies. For example in the earths magnetic field of 0.5 gauss, NMR effects should occur at 2129.7 Hz.

Detailed Description Text (53):
Utilizing the linear amplifier of the present invention, the plasma tube may produce approximately 125,000,000 microwatts of power entering the plasma tube, the actual power being modulated by the light waves being unknown. The result in transmitted power, measured especially in the UV region, at this time, is not directly ascertainable. The light energy given off may be measured with various well known instruments, but the measurement does not truly indicate the power of the UV wave.

Detailed Description Text (56):
The internal electrodes of the plasma tube may vary quite a bit. If using standard or common Neon sign tubing, cold cathode type electrodes with flexible woven connecting leads for power input should be used. Electrodes with solid copper connecting leads will quickly break the wire lead. The two internal electrodes are known as a cathode and an anode. The anode in this unit should be a piece of round barstock with a sloping face on it, attached to the tube. The cathode may be a piece of the same round barstock except that it generally has a flat face perpendicular to the anode support. The anode has an angle on its face between 17.degree. and 22.degree.. The greater the anode angle, the more energy required for a particle to leave the face of the anode parallel to the cathode face. The narrower the anode face angle, the less energy that is needed for a particle to leave the anode face parallel to the cathode face. As a result, the main beam comes out of the tube at a glancing angle, instead of at 90.degree., therefore the subject being treated will have to be positioned accordingly.

Detailed Description Text (57):
The cathode may be formed with a point in the center of it to better disperse the radio frequency energy. The cathode may be nothing more than a pointed tip at the end of the support rod. The cathode also may be round and flat faced with multiple sharp needles projecting outward toward to anode. As a rule, the anode and cathode should not be placed nearer than 1 cm. apart, preferably around 2.5 cm. apart. This is exemplified in FIG. 5. The tube 16 is shown containing anode 30 and cathode 32. The anode 30 has a flat angled face 34. The cathode 32 has a flat face 36 with a plurality of sharp needles 38 projecting therefrom.

Detailed Description Text (58):
The anode and cathode should be constructed from non-porous, heat-tolerant material, such as steel, stainless steel, tungsten, kovar, tantalum or nickel/chrome-plated brass. Porous metals, such as silver, gold, brass, tin, aluminum and copper, trap small amounts of gases and impurities that may leak into the tube over time and contaminate it. Further, the electrodes do become quite hot under the influence of radio frequency, thus some metals may melt, destroying the tube.

Detailed Description Text (62):
The precise nature of a plasma wave, the energy produced in a plasma tube, is not clear. One theory has it that the radio wave, with its attached or modulated audio wave, is attached to the light generated in the plasma tube. Possibly, the light waves are modulated onto the radio-audio waves. Yet another theory is that an entirely new form of energy is created which has properties common to sound, light and radio waves, but also properties which are not common.

Detailed Description Text (63):
Within the plasma tube, the audio frequency is spread about longitudinally, the light travels in longitudinal waves and the radio waves are disbursed vertically or horizontally from a standard antenna. The vector interface of these three forms of vibration in cellular structures may be a contributing factor in the device's ability to cause the devitalization of small organisms. The heterodyning occurring within the plasma tube also may account for literally thousands of different frequencies.

Detailed Description Text (64):
The magnetic field component in an RF wave travels transversely, and the electrical wave component travels vertically. It is unknown how the wave emanating from the plasma tube travels. It is hypothesized that the wave from the plasma tube may be of a magnetic nature.

Detailed Description Text (65):
Although the above has been directed primarily toward eradication of malignant cells, the device also may be employed for other beneficial purposes. During development of the present device, it was observed that insects were irritated by the transmitted waves. Although sustained large doses transmitted waves may be lethal to human beings, experimentation with frequency and power levels should result in a device that is harmless to humans, yet annoying to insects such that they are driven from an area, such as a house or farmer's field. The output signal of the present device may be directed toward an insect population to drive them from a location.

Detailed Description Paragraph Table (2):
TABLE II Range of Spectral Lines GAS RANGE Argon 487 to 23,966 Helium 231 to 40,478 Krypton 729 to 40,685 Neon 352 to 33,834 Xenon 740 to 39,955 Mercury.sup.1 893 to 36,303 .sup.1 Mercury, when added to the above gases, may decrease the power necessary to initiate the lighting of the plasma.

Detailed Description Paragraph Table (3):
TABLE III Germicidal Energy BACTERIAL ORGANISM UV ENERGY (uw-sec/cm.sup.2) B. Anthracis (Anthrax) 4520 Salmonella Enteritidis (Food 4000 Poisoning) C. Diphtheriae (Diphtheria) 3370 E. Coli (Food Poisoning) 3000 N. Catarrhalis (Sinus Infection) 4400 P. Aeruginosa (Various Infections) 5500 Dysentery Bacilli 2200 Staph. Aureus (Various Infections) 2600 Strep. Viridans (Various 2000 Infections)

CLAIMS:

1. A therapeutic method for treating a tissue comprising the steps of: exposing the tissue to an output signal of a gas plasma the gas plasma formed by subjecting a gas to:

an audio wave having an audio frequency; and

a radio wave having a radio frequency.

2. A method as recited in claim 1, the output signal further comprising a light wave having a light frequency, the frequency of the light varying with the type of gas, the audio frequency and radio frequency.

4. A method as recited in claim 1, wherein said radio wave is pulsed to excite the gas into a plasma.

5. A method as recited in claim 4, wherein said radio wave is pulsed at the frequency of the audio wave to excite the gas into a plasma.

6. A method as recited in claim 4, wherein a duration of each radio wave pulse varies with a frequency of said audio waves.

7. A method as recited in claim 4, wherein a power of the output signal is proportional to the audio frequency.

8. The method of claim 1, wherein one watt of radio frequency power is used per pound of body weight of a patient.

13. A method for treating tissue, comprising:

providing a gas in a tube,

exciting the gas into a plasma to create a signal, and

exposing tissue to the signal created by the gas plasma,

wherein the gas is excited into a plasma by applying an audio wave and a radio wave to the tube.

14. The method of claim 13, wherein the gas plasma signal is pulsed by pulsing said radio wave and audio wave.

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**** See image for Certificate of Correction ****
TITLE: Magnetic resonance force microscopy with oscillator actuation

Abstract Text (1):
The present invention provides a magnetic resonance force microscopy apparatus and method for use in combination with an oscillator. The oscillator has a motional body and one member of a sample/magnet pair is disposed on the motional body. The present invention actuates the motional body. The apparatus comprises a holder adapted to mount the second member of a sample/magnet pair, an RF field generator positioned to apply a field to the sample, a motion sensor adapted to be coupled with the motional body, an actuator adapted to be coupled with the motional body, and a motion controller coupled with the actuator and with the motion sensor. The actuation effort can dampen the vibrational amplitude of the oscillator that would otherwise diminish the spatial resolution of the device; control the oscillator dynamical properties to allow more stable signal detection; vary the distance between the magnetic tip and the sample material for sample scanning and field modulation; apply actuation and control signals to help prevent the oscillator from contacting and sticking to the sample material or other device components; provide a method for calibrating instrument subsystems; provide a way for controlling all oscillator vibrational modes, including torsional modes; and provide a way to apply feedback control to the oscillator, thereby gaining dynamic advantages.

Brief Summary Text (2):
Magnetic resonance force microscopy (MRFM) is a variant of scanning probe microscopy that combines the sensitivity and spatial resolution of atomic force microscopy with the three-dimensional and nondestructive imaging capabilities of magnetic resonance imaging. Sample imaging entails mechanically detecting the interaction between sample spins as they undergo magnetic resonance with a nearby gradient magnet. Magnetic resonance phenomena can be detected and imaged by mounting either the sample or the gradient source on a mechanical oscillator and sensing changes in oscillator motion that are induced by magnetic resonance.

Brief Summary Text (3):
Sidles first conceived of the theory of magnetic resonance force microscopy, with potential application as a molecular imaging technology, in the early 1990's. The theory and potential applications of MRFM imaging are described in several early articles (for example, Sidles et al., "The theory of oscillator-coupled magnetic resonance with potential applications to molecular imaging" Review of Scientific Instruments, vol. 63, pp. 3881-3899 (August 1992)). A review article broadly describing magnetic resonance force microscopy was published after further theoretical development and experimental demonstration of the concept of MRFM imaging (Sidles et al., "Magnetic resonance force microscopy" Reviews of Modem Physics, vol. 67, pp. 249-265 (January, 1995)).

Brief Summary Text (4):
Three US patents have also been issued in the field. In U.S. Pat. No. 5,166,615, Sidles discloses a method for mechanically detecting magnetic resonance. A modulation technique patented by Rugar et al. in U.S. Pat. No. 5,266,896 provides a means for creating signals that are easier to detect. In U.S. Pat. No. 5,619,139, Holezer et al. describes an MRFM device in which a spin at the tip of the gradient magnet undergoes magnetic resonance while in atomic interaction with sample spins, thereby scanning sample surfaces.

Brief Summary Text (5):

In force detected magnetic resonance, the basis for magnetic resonance force microscopy, there is a magnetic force between the sample material and the magnetic tip. If either the sample material or the magnetic tip are affixed to a mechanical oscillator, magnetic resonance in the sample can cause a fluctuating force between the sample and the tip that produces detectable changes in oscillator motion. The oscillator is typically a cantilever supported at the base.

Brief Summary Text (7):
where M and v are the magnetization and volume of the sample material. In addition, the magnetic field produced by the magnetic tip alters the magnetic polarization field of the sample material. The inhomogeneity in polarization field enables the generation of magnetic resonance in a portion of the sample, providing the spatial resolution necessary to image sample features.

Brief Summary Text (8):
More lengthy descriptions of mechanically detected magnetic resonance and magnetic resonance force microscopy are contained in the references previously cited, notably the patents, the Sidles Review of Scientific Instruments article, and the Sidles Reviews of Modern Physics article.

Brief Summary Text (10):
(a) The inherent thermal energy in the oscillators causes vibrations that are often the dominant source of experimental noise. The noise resulting from thermal energy hinders the creation of the MRFM signals and decreases the image resolution of the device.

Brief Summary Text (16):
Also, previous methods of detecting magnetic resonance use an analog implementation of feedback controller dynamics. Such analog controllers are difficult to configure and adjust. Furthermore, these analog implementations do not adapt to changing feedback requirements.

Brief Summary Text (19):
This invention provides oscillator actuation and control in devices that mechanically detect magnetic resonance for modifying the natural dynamic properties of the oscillator, and controlling oscillator motion to track a reference signal. Actuation and control are achieved by the application of actuation effort directly to the oscillator at a location that undergoes oscillatory motion. A number of beneficial changes in oscillator motion can result from selecting and implementing an appropriate motion controller. Three of the most important ways that feedback control can alter oscillator motion are in damping the vibration amplitude of the oscillator, modifying the natural dynamic properties of the oscillator, and controlling oscillator motion to track a reference signal. Additional benefits include reducing spurious oscillator vibrations, enhancing the spatial resolution of the images, aiding in signal production and preventing "snap-in".

Brief Summary Text (20):
The present invention is a magnetic resonance force microscopy apparatus for use in combination with an oscillator. The oscillator has a motional body and one member of a sample/magnet pair disposed on the motional body. The apparatus comprises a sample/magnet holder adapted to mount the second member of a sample/magnet pair, a radio-frequency (RF) field generator positioned to apply a RF field to the sample, a motion sensor adapted to be coupled with the motional body, an actuator adapted to be coupled with the motional body, and a motion controller coupled with the actuator and with the motion sensor. The motion controller is responsive to signals it receives and uses the actuator to control the motional body of the oscillator. Reference signals are optionally included in the input of the motion controller. One of the central ideas in the present invention is that it is advantageous to apply actuation effort directly to the motional body of the oscillator, rather than actuating by indirectly deflecting the base of the oscillator.

Brief Summary Text (21):
The term "magnet" as used herein, refers to any material responsive to changes in a magnetic field. A preferred embodiment has a permanent magnet positioned on the motional body. Alternatively, the magnet is positioned on the sample/magnet holder. In a preferred embodiment, the RF fields are generated by a coil, the magnetic actuation field is generated by a solenoid, the motion controller is a digital motion controller and the motion sensor is a fiber-optic system. Preferred actuators are magnetic, electrical, optical, thermal, piezoelectric, magnetostrictive and

mechanical. In other preferred embodiments, the magnetic field generator produces a magnetic field substantially parallel to the motional body. "Substantially parallel" refers to a magnetic field having the largest component in the parallel direction.

Brief Summary Text (22):
The term "radio-frequency (RF) field" as used herein, refers to any frequency in the radio spectrum. Radio-frequency fields of differing frequencies are useful for different magnetic resonance force microscopy applications.

Brief Summary Text (23):
The present invention also provides a method of oscillator actuation in a magnetic resonance force microscopy system having an oscillator that has a motional body. The motional body moves in response to magnetic resonance in a sample. The method of oscillator actuation consists of inducing magnetic resonance in a sample, detecting the motion of the motional body, and applying actuation effort to the motional body of the oscillator. One favorable aspect of the method of oscillator actuation is the prevention of sticking of the oscillator to another member of the magnetic resonance force microscopy system. Another favorable aspect of the method of oscillator actuation is the ability to vary the sample polarization field by adjusting the oscillator position, and thus the spacing between the sample and the magnet in the sample/magnet pair. Variations in this polarization field can be used to scan different portions of the sample or to modulate the polarization field to aid in signal generation.

Brief Summary Text (24):
The magnetic resonance force microscopy system can be calibrated in response to application and detection of periodic motion of the oscillator. Preferably, the sample is not undergoing magnetic resonance while calibration is being performed.

Brief Summary Text (25):
Oscillators with a low spring constant are desirable for the mechanical detection of magnetic resonance because they have a lower thermal noise floor. For a simple cantilever oscillator the uncontrolled root-mean-square (rms) Brownian amplitude of oscillator vibrations is ##EQU2##

Brief Summary Text (33):
There are at least two additional advantages to be gained by the application of actuation effort to the motional body of the oscillator in devices for the mechanical detection of magnetic resonance. This type of actuation enables collocated feedback control and control of torsional modes of the oscillator.

Brief Summary Text (36):
Controlling the motion of the oscillator offers several advantages over uncontrolled systems. One capability of control is a reduction in the amplitude of spurious oscillator vibrations. Reducing the Brownian amplitude of the oscillator vibration (see Equation 1) aids experiments in at least three ways. First, the spatial resolution of MRFM devices is generally limited to the thermal vibrational amplitude of the oscillator. Therefore damping the Brownian amplitude with control can enhance the spatial resolution of MRFM images. Second, thermal vibration of the oscillator makes the production and detection of magnetic resonance more difficult because the sample polarization field fluctuates with amplitude ##EQU6##

Brief Summary Text (37):
where B.sub.x is the component of the magnetic field produced by magnetic tip in the x-direction and .differential.B.sub.x /.differential..sub.x is the gradient of this magnetic field component. These fluctuations are undesirable because a sample in a constant applied RF field will only undergo magnetic resonance within a limited range of polarization fields. Thus the application of control that damps the oscillator amplitude also aids signal production. Third, reducing the oscillator amplitude with feedback control techniques can help prevent "snap-in". By damping excursions of the oscillator, it is possible to scan close to the sample materials with a reduced likelihood that the magnetic tip will contact and stick to the sample.

Brief Summary Text (38):
A second major way in which feedback control can favorably alter oscillator motion is the modification of the natural dynamic properties of the oscillator. One of the most important ways that feedback control can alter oscillator dynamics is in damping oscillator motion, resulting in a lower resonant quality Q and damping time

.tau.. The expression previously given in Equation 2 for the power spectral density of the Langevin force that is often the dominant experimental noise source indicates that using high resonant quality oscillators is advantageous. While such oscillators have a lower thermal noise floor, their natural properties are unwieldy for signal detection. The bandwidth of the spectral response of an oscillator is approximately .DELTA..omega.=.omega..sub.n /Q . Thus the high quality oscillators have a narrow response bandwidth. This narrow frequency response complicates signal detection because the natural frequency of the oscillator often drifts in response to changing experimental conditions. These small drifts can cause large changes in the motional response of a high quality oscillator, as evident from the transfer function given in Equation 4.

Brief Summary Text (39):
In addition to a narrow response bandwidth, high resonant quality oscillators also have a long damping time .tau.=Q/.omega..sub.n. Because the oscillator energy decays with the damping time, detection with oscillators having a long damping time is slow. By designing and implementing an appropriate motion controller, the response of the oscillator can be damped. This damped motion has a wider response bandwidth and a shorter damping time providing more stable and faster experimentation.

Brief Summary Text (40):
Another capability of a motion control system is the ability to produce desired oscillator motion by tracking a reference signal. Such tracking is similar to driving the cantilever and is useful for the same reasons: field modulation, sample scanning, device calibration, and improving experimental stability. The benefits to be gained by operating a device for mechanical detection of magnetic resonance with a driven oscillator were previously mentioned. The operation and performance of a device with a motion control system to achieve these benefits differs because all the previously mentioned benefits of cantilever control, such as reduced damping time and spurious vibrational amplitude, can be achieved while tracking the reference signal.

Drawing Description Text (2):
FIG. 1A is a schematic diagram of an apparatus for mechanically detecting magnetic resonance signals containing an actuator.

Drawing Description Text (5):
FIG. 2 is a diagram illustrating one implementation of the present invention, which includes an RF generator, fiber-optic interferometer and motion controller.

Drawing Description Text (18):
FIG. 7 shows plots of the power spectral density of oscillator motion when zero(A), light(B), moderate(C), and strong damping(D) are added by a motion control system.

Detailed Description Text (3):
The invention consists of an apparatus for mechanical detection of magnetic resonance signals that has an actuator that can be used to induce oscillator motion, cancel oscillator motion, or alter oscillator dynamics. An actuator as defined herein provides actuation effort to the motional body of an oscillator in order to induce motion therein. Actuation effort may be a force or a torque. FIG. 1A depicts a simplified representation of this apparatus. Oscillator 10 responsive to a magnetic resonance signal is acted upon by actuator 40. The motion of the oscillator resulting from magnetic resonance and/or actuation is detected by motion sensor 20. FIG. 1B shows this basic apparatus with the addition of a signal source 30 coupled to the actuator. FIG. 1C shows the basic apparatus with the addition of a motion controller 32, responsive to the measured motion of the oscillator and coupled to the actuator.

Detailed Description Text (4):
In operation, the MRFM apparatus contains a mechanical oscillator, a magnetic tip and a sample material containing magnetic spins having a spin resonance frequency. A magnetic tip is a magnetic material of appropriate size, shape and polarization to produce a magnetic field distribution for the production of MRFM signals. The field distribution often includes a gradient with distance scales smaller than the sample. The sample material and magnetic tip are brought into close proximity, with one of them being mounted on the mechanical oscillator. If the sample is mounted on the mechanical oscillator, a holder is used to mount the magnet. If the oscillator contains a magnetic tip, a holder is used to mount the sample. This holder can be any suitable material. The holder can also be capable of translating in the x-, y-

and z- directions. When magnetic resonance occurs in the sample material, the sample magnetization changes causing a magnetic force between the sample and the magnetic tip. This force results in oscillator motion. A motion sensor capable of detecting oscillator motion and an actuator that applies actuation effort to the oscillator are also present. The motion sensor is adapted to be coupled with the oscillator. In addition to these elements, a signal source may be present to induce oscillator motion. Alternately, or in addition, a motion controller may be present to induce oscillator motion, cancel oscillator motion, or alter the oscillator dynamics.

Detailed Description Text (5):
FIG. 2 shows a diagram of a preferred embodiment of the present invention. At the heart of this device is a mechanical oscillator 10 with a magnetic tip 14 located in close proximity to sample material 12. A nearby radio-frequency (RF) coil 16 delivers RF power from RF generator 18 to the sample material. Optical fiber 24 is part of a fiber-optic interferometer 22 that senses the motion of the oscillator. Actuation is provided using a solenoid driver 46 and solenoid 44 to apply magnetic fields to the magnetic tip. The signals coupled to the solenoid driver may be generated by a motion controller 32 which may include a signal source.

Detailed Description Text (6):
FIG. 3A shows another representation of the torsional magnetic actuation system used in the apparatus of FIG. 2. Oscillator 10 has an actuation magnet 48 disposed at a location that undergoes resonant motion. The actuation magnet may be any magnetic material. In FIG. 2 the actuation magnet is the same magnetic tip 14 used to detect magnetic resonance signals. In FIG. 3A, a magnetic field source 42 applies magnetic fields to the actuation magnet. One source of magnetic fields is a solenoid (coil). The actuation magnet is illustrated near the end of the oscillator, but could be located anywhere on the motional body.

Detailed Description Text (9):
The magnetic interaction between a sample material that undergoes magnetic resonance and a magnetic tip is the basis for mechanically detected magnetic resonance. By applying appropriate magnetic polarization and radio-frequency fields to the sample material, magnetic resonance alters the sample magnetization. The induced changes in sample magnetization acting upon the magnetic tip cause detectable changes in the motion of the oscillator.

Detailed Description Text (10):
FIG. 2 presents one embodiment of a device for force detected magnetic resonance with magnetic tip 14 located on oscillator 10. In this embodiment, the magnetic tip is the sole source of the sample polarization field. Additional magnetic polarization fields can also be applied from external sources. The combination of this polarization field and an RF field generated by RF field generator 18 and applied with RF coil 16 causes magnetic resonance in sample material 12. Any other method of generating radio-frequency fields can be used including, but not limited to, multiple coils, stripline oscillators, tuned cavities and resonant circuits. The magnetic resonance alters the force between the magnetic tip and the sample material, producing detectable changes in the oscillator motion.

Detailed Description Text (15):
The specific configuration of torsional magnetic actuation depicted in FIG. 2 has two inherent advantages over alternate configurations. First, the magnetic tip 14 also serves as the actuation magnet (48 in FIG. 3A), thus simplifying the device. In the event that the magnetic tip has insufficient magnetic moment to serve as the actuator magnet, additional magnetic material can deposited on the oscillator. The second advantage of this configuration is that by using magnetic tip 14 for torsional magnetic actuation, applied actuation fields are automatically applied substantially perpendicular to the polarization direction of the magnetic tip. For these reasons, torsional magnetic actuation acting directly upon the magnetic tip 14 is a natural choice for actuation in devices for mechanical detection of magnetic resonance.

Detailed Description Text (16):
Coupling a signal source to the actuator for driving the oscillator with a desired periodic waveform is useful for field modulation, sample scanning, device calibration, and improving experimental stability. The most desired waveform is a sinusoid, but other waveforms can be used. Modulation of the polarization field of the sample material by driving the oscillator occurs as a result of relative motion in the presence of a field gradient. The inhomogeneous magnetic field produced by

the magnetic tip has a magnitude that varies as a function of distance from the magnetic tip. Thus by driving the oscillator, and hence changing the separation between the magnetic tip and the sample material, the magnitude of the magnetic field at the sample material can be adjusted. Adjusting this field is useful for modulating the magnetic resonance in the sample material and therefore aids in producing detectable signals.

Detailed Description Text (17):
By using actuation to vary the spacing between the magnetic tip and the sample material, different portions of the sample can be made to undergo magnetic resonance as the polarization field changes. Thus by driving the oscillator, and hence changing the polarization field in the sample material, applied actuation effort can be useful for sample scanning. Actuation effort and hence sample scanning has utility for AC and DC sample scanning. AC scanning refers to generating dynamic changes in oscillator position, so that different locations in the sample are sensed using magnetic resonance. DC scanning refers to motion of the oscillator to a static location.

Detailed Description Text (18):
Driving the oscillator can be further useful for measuring oscillator properties such as natural frequency and resonant quality. These parameters can be ascertained from the dynamical response of the oscillator to a stimulus such as applied actuation. Driving the oscillator can also help calibrate instrument subsystems such as a motion sensor. For example, calibration of fiber-optic interferometer 22 of FIG. 2, can be accomplished by driving the cantilever and monitoring the interferometer output. If the oscillator amplitude is sufficient, the maximum and minimum intensities of the optical interference pattern can be recorded. These values can then be used together with known parameters, such as the wavelength of the light used for detection, to calibrate the fiber-optic interferometer. Another method for calibrating the interferometer involves the use of the maximum and minimum intensities of the optical interference pattern from static deflection of the oscillator. Other calibration methods are known to those skilled in the art.

Detailed Description Text (19):
Finally, actuation of the oscillator can help improve the stability of devices that mechanically detect magnetic resonance signals. Sometimes electrostatic and other interactions will cause the oscillator to stick to the sample material or other components such as the motion sensor. Oscillators that have a low spring constant that are operated in close proximity to samples are particularly prone to this "snap-in" Driving the oscillator can be a useful technique to allow the oscillator to approach the sample without "snap-in". By driving the oscillator to an appropriate amplitude before bringing it close to the sample material, the energy in the oscillator resists "snap-in".

Detailed Description Text (25):
An additional note on the operation of motion control systems is that the benefits are achievable without a loss in the experimental signal-to-noise ratio (snr). The snr of an experiment performed in both open- and closed-loop systems is identical provided that the motion controller itself does not introduce additional noise.

Detailed Description Text (31):
Alternative embodiments of the present intention can have various means for generating a mechanically detected magnetic resonance signal, various oscillators, various means for sensing the motion of the oscillator, various means for actuating the oscillator, and various motion controllers.

Detailed Description Text (32):
The aforementioned embodiment depicted in FIG. 2 uses force detected magnetic resonance with a magnetic tip disposed on the oscillator. Force detected magnetic resonance may have either sample material or the magnetic tip mounted on the oscillator. If the sample is mounted on the oscillator, another magnet may be mounted on the oscillator for actuation purposes. In addition, the specific location on the oscillator where these elements are mounted is not to be limited to the tip, nor is the specific polarization direction of the magnetic tip limited to the easy axis of oscillator motion. Configurations in which the magnetic tip or sample material are disposed on any part of the oscillator that undergoes resonant motion, and are oriented in any direction, are viable alternatives for mechanically detected magnetic resonance. It is preferable to have the sample on the sample/magnet holder to facilitate changing the sample when different samples are scanned. It is possible

to position the gradient magnet on the sample/magnet holder when fabrication techniques hinder the inclusion of the gradient magnet on the oscillator.

Detailed Description Text (33):
The mechanically detected magnetic resonance signals of the present invention should not be limited strictly to those involving the generation of magnetic forces between the magnetic tip and the sample. Devices in which a torque on the oscillator, rather than a force, is generated by the magnetic resonance interaction will similarly benefit from the application of the actuation and control techniques of the present invention. In practice, the magnetic resonance phenomenon alters the energy of the system containing the sample material and magnetic tip, thereby effecting the motion of the oscillator in a detectable manner. Various means by which this energy interaction can effect the oscillator motion are readily apparent to those skilled in the art. Thus the actuation and control techniques disclosed by this patent are readily applicable to a variety of devices for the mechanical detection of magnetic resonance. Oscillator 10 described in the preferred embodiment was a simple cantilever beam operating in a displacement mode. However, under some circumstances it may be advantageous to use alternate oscillators as signal detectors. The present invention may be applied to torsional oscillators, membrane oscillators, "guitar string" type oscillators, and cascade oscillators, in which multiple coupled oscillators are combined. Detection devices may also find advantage in the use of multiple oscillators for simultaneous detection of signals. The use of multiple oscillators would allow scanning multiple regions of a sample simultaneously, enhancing the speed of the imaging process.

Detailed Description Text (34):
The preferred embodiment also uses a motion sensor consisting of a fiber-optic interferometer. A variety of alternate motion sensors can be utilized for sensing oscillator motion, including, but not limited to, sensors based upon the angle that light reflects from the oscillator, the tunneling current between a probe and a conductive oscillator, variations in capacitance between a conductive oscillator and a nearby surface, variations in oscillator piezoresistivity and voltage from piezoelectric oscillators.

Detailed Description Text (36):
There are several ways to provide actuation effort with an applied magnetic field B(t). FIG. 3A depicts torsional magnetic actuation, which was previously described. FIG. 3B shows a magnetic field source 42 acting on an actuation magnet 48 to produce a magnetic actuation force. FIG. 3C depicts an oscillator 10 with a magnetostrictive material 50 such that the application of magnetic fields from a magnetic field source 42 flexes the lever. Magnetic fields can be generated in a number of ways, including using a solenoid or permanent magnet. It may be desirable to apply the magnetic actuation fields using the same components used to generate the RF field, such as a coil, because this simplifies the apparatus.

Detailed Description Text (39):
FIG. 3G shows a cantilever being deflected by photon pressure. Optical power 72 produced by an optical source 70 either reflects off or is absorbed by the oscillator. The resultant momentum transfer can actuate the oscillator. In FIG. 3H a mechanical vibrator 80 directly applies actuation effort to oscillator 10. In FIG. 3I energy 92 applied to the cantilever from a heat source 90 causes a portion of the oscillator to heat faster than a different portion of the oscillator. The differential expansion rates can actuate the cantilever by thermoelastic bending. One source of heat that can be used is power from an optical source.

Detailed Description Text (44):
Adaptive control employs a motion control system with the ability to adapt to changes in the behavior of the oscillator or to changing feedback requirements. Oscillator properties are known to vary in devices that mechanically detect magnetic resonance. As the temperature and pressure of the device, or spacing between the magnetic tip and sample material changes, the oscillator can change undergo dynamic changes such as shifts in resonant frequency and quality. These changes complicate experiments and motivate the use of controllers that sense changes in the oscillator and adapt to continue to provide adequate motion control. Adaptive control may also be motivated by changing feedback requirements such as the desire to control the cantilever to a large amplitude. For example, controlling to large amplitudes often requires reconfiguration so that larger experimental signals are kept within the operational limits of all circuit components. In adaptive controllers, the controller is modified when these needs arise.

Detailed Description Text (46):
Accordingly, the reader will see that the method and apparatus for actuation and control in devices for mechanically detecting magnetic resonance can aid detection by altering the motion of the oscillator. The device we describe can advantageously:

Other Reference Publication (9):
Rugar, D. et al., "Force detection of nuclear magnetic resonance," (Jun. 1994) Science 264:1560-1563.

Other Reference Publication (14):
Sidles et al., "The theory of oscillator-coupled magnetic resonance with potential applications to molecular imaging" (Aug. 1992) Review of Scientific Instruments, 63:3881-3899.

Other Reference Publication (15):
Sidles et al., "Magnetic resonance force microscopy"(Jan. 1995) Reviews of Modern Physics, vol. 67, pp. 249-265.

Other Reference Publication (17):
Wago, K. et al., "Low-temperature magnetic resonance force detection," (Mar./Apr. 1996) J. Vac. Sci. Technol. B 14(2):1197-1201.

Other Reference Publication (18):
O. Zuger et al., "Three-dimensional imaging with a nuclear magnetic resonance force microscope," (Feb. 1996) J. Appl. Phys. 79(4):1881-1884.

Other Reference Publication (19):
Zuger, O. and Rugar, D., "Magnetic resonance detection and imaging using force microscope techniques (invited)," (May 1994) J. Appl. Phys. 75(10):6211-6216.

CLAIMS:

1. A magnetic resonance force microscopy apparatus for use in combination with an oscillator, said oscillator having a motional body and having a first member of a sample/magnet pair disposed on said motional body, said apparatus comprising:

a sample/magnet holder adapted to mount a second member of a sample/magnet pair;

an RF field generator positioned to apply a field to said sample;

a motion sensor adapted to be coupled with said motional body;

an actuator adapted to be coupled with said motional body; and

a motion controller coupled with said actuator and with said motion sensor.

4. The apparatus of claim 1, wherein said RF field generator comprises a coil.

18. The apparatus of claim 1, wherein said motion controller delivers a signal to said actuator in response to said motion sensor, wherein the dynamic response of said motion controller is adapted in response to changes in said magnetic resonance force microscopy apparatus.

32. The apparatus of claim 1, wherein said RF field generator serves as part of said actuator by additionally generating actuation fields.

33. A method of oscillator actuation in a magnetic resonance force microscopy system, said system having an oscillator having a motional body, said motional body movable in response to magnetic resonance in a sample, said method comprising the steps of:

inducing magnetic resonance in said sample;

detecting motion of said motional body; and

applying actuation force to said motional body of said oscillator.

36. The method of claim 35, further comprising the step of calibrating said system in response to detected motion of said motional body wherein said step of calibration is performed before, after or simultaneously with the step of inducing magnetic resonance.

37. A method of preventing sticking of said oscillator to another member of said magnetic resonance force microscopy system comprising the method of claim wherein said motional body motion undergoes periodic motion with an amplitude sufficient to prevent sticking of said oscillator to said other member.

38. The method of claim 33 wherein said magnetic resonance force microscopy system comprises:

a sample/magnet holder adapted to mount the second member of a sample/magnet pair;

an actuator adapted to be coupled with said motional body; and

a motion controller coupled with said actuator and with said motion sensor.

DOCUMENT-IDENTIFIER: US 6368275 B1
TITLE: Method and apparatus for diagnostic medical information gathering, hyperthermia treatment, or directed gene therapy

Abstract Text (1):
A micro-instrument suitable for property imaging in a body is less than one millimeter in each dimension. The micro-instrument includes a base having a first wall and a second wall, the second wall substantially circumscribing the first wall, and a lid connected with the base to form a cavity and the lid being temporarily deformable. Optionally, the lid can include a cantilever that is deformable. Also optionally, an electronic circuit can be attached with the micro-instrument. The micro-instrument can also be substantially spherical. An observable property of the micro-instrument varies as a function of a physiological property of the body.

Brief Summary Text (3):
Radio frequency ("RF") identity-card devices and micro-tags can be inserted under the skin of a pet. These tags currently merely transmit an identification signal that uniquely identifies the animal. They are too large to be used for measuring parameters throughout a tissue volume such as temperature or pressure.

Brief Summary Text (7):
In a second aspect, a medical diagnostic ultrasound system for observing a physiological property of a body is provided. The system includes a transmit beamformer operable to transmit ultrasonic energy into the body. A micro-instrument particle has an observable property responsive to the ultrasonic energy where the observable property varies as a function of the physiological property of the body.

Drawing Description Text (7):
FIG. 5 is a view of a transducer probe and a section of a body containing the heart;

Detailed Description Text (2):
Magnetic resonance imaging ("MRI") and ultrasound may be used to measure or map temperature in the human body. Ultrasound has also been used to map pressure in the body. With MRI, a thermally sensitive contrast agent has been demonstrated. Pressure information, such as ultrasound-derived blood pressures in the heart's chambers, may allow cardiologists to better assess the health and performance of the cardiovascular system. Temperature monitoring using either MRI or ultrasound on a fine scale may be extremely useful for the control of a variety of tissue-heating or cooling therapies designed to kill cancer, such as hyperthermia as done by ultrasound, microwave or RF heating of targeted tissue. A real-time (e.g. several samples per second) temperature mapping capability may aid in these and other developing treatments.

Detailed Description Text (7):
The micro-instruments are manufactured to provide an observable characteristic through mechanical (e.g., acoustic) and/or electrical mechanisms. Referring to FIG. 1, a micro-instrument for providing an acoustic response through a mechanical acoustic mechanism is shown. For example, a response signal indicative of the property being measured is transmitted (or returned) from the micro-instrument 100. The response signal contains data relating or relatable to bodily parameters. When the response signal is initiated at the micro-instrument 100 an incoming initiation signal is not required to obtain the bodily parameter information. Alternatively, the observable property is initiated responsive to externally created energy. For example, external insonification or RF radiation is transmitted into the body toward

the microinstrument, and energy is indirectly or directly reradiated by the micro-instrument 100. Regardless of the source of the energy, the observable property contains information relating to one or more desired local physiological parameters and is contained in the response or signature of the microinstrument(s).

Detailed Description Text (8):
In the case of in-coming insonification energy, the response may consist of the changing vibration energy spectrum characteristic of a vibrating or bending sub-member such as a cantilever 202. (FIG. 2). In the case of an in-coming RF radiation signal, the response signal may be an RF or other electromagnetic signal containing the desired data transmitted from an on-board micro-instrument antenna.

Detailed Description Text (10):
An isometric view of a micro-instrument 100 of one preferred embodiment is shown in FIG. 1 with a cut-out section showing a cavity or chamber 110. The micro-instrument 100 includes a base 102 and a lid 104. The base 102 has a first wall (floor) 106 that forms the floor of the micro-instrument, and a second wall 108 that circumscribes the first wall 106. The micro-instrument 100 has a cylindrical shape with a diameter d and a thickness or height t1. Other shapes may be used, such as a cube, a box, a sphere, a rod, or more complex shapes. Preferably, the thickness is less than the diameter to form a vibratable or deformable lid or plate 104 and/or 106. The diameter is preferentially between 100 microns and 1 micron or even sub-micron. For example, the micro-instrument 100 has a diameter in the range of d=30 to 0.1 microns, or preferably a diameter of d=12 to 0.5 microns. The size tolerances may be tightly controlled using industry accepted I.C. and MEMS fabrication processes. For example, d=5 microns +/-2% and t1 =1.0 microns +/-2% are achievable using the manufacturing techniques described above.

Detailed Description Text (11):
The micro-instruments 100 may also be smaller than conventional contrast agents, which typically are between 2 and 7 microns in (spherical) diameter. It is desirable to minimize the size and dosage of the micro-instrument 100 to reduce problems relating to microembolisms of the heart or brain caused by agglomeration. Unlike conventional contrast agents, these micro-instruments may have very long lifetimes and may be used with low doses since even at low doses many measurements per cubic centimeter are provided.

Detailed Description Text (20):
Referring to FIG. 2, the micro-instrument 100 is illustrated in one embodiment as having a bendable cantilever 202 in the lid 104. The cantilever 202 is suspended by one end and hangs over the cavity 110 (FIG. 3). The cantilever 202 is vibrated up and down by externally applied acoustic energy. In the case of measuring temperature, the cantilever 202 preferably comprises a bimetal having a resonant frequency which is a function of temperature or by bottoming out on the interior chamber floor at a specific temperature via thermal bending. A bimetal layer for the cantilever 202 is indicated by laminate material interface 104a of FIG. 3.

Detailed Description Text (24):
The fundamental mechanics of a vibrating beam in air are described as follows:

Detailed Description Text (26):
E is the modulus of elasticity of the beam material

Detailed Description Text (27):
I is the moment of inertia of the beam section

Detailed Description Text (29):
w is the weight/unit length of the beam

Detailed Description Text (30):
L is the beam length

Detailed Description Text (31):
And **N means raised to the power of N

Detailed Description Text (39):
As discussed above, the micro-instrument in one embodiment includes an electrical device such as an electrical sensor for at least one of generating the observable characteristic or influencing the observable characteristic as a function of a

physiological property. FIG. 4 shows a micro-instrument electronic circuit 402. The electronic circuit 402 includes a micro-instrument receiver 406, a micro-instrument transmitter 408, and a micro-instrument processing, logic and/or memory unit 404. The receiver 406 in the micro-instrument 100 receives initiation signals from an external transmitter 502 (FIG. 5). The external transmitter 502 may send one or both of an acoustic signal or an electromagnetic signal to initiate data retrieval from micro-instruments 100. In the case of an electromagnetic signal, the receiver R is an electromagnetic receiver coupled to a micro-instrument 100 antenna. Such a transmitter/receiver is an RF or other frequency-range system.

Detailed Description Text (40):
Using known identification-tag technology, power may be provided to the micro-instrument 100 through the micro-instrument antenna. The transmitter 408 of the micro-instrument transmits electromagnetic response signals to an external receiver 504 (FIG. 5) of the probe 500, in the case in which that signal is electronic as opposed to acoustic. The micro-instrument 100 generates the response signal as a function of a body parameter, such as temperature.

Detailed Description Text (44):
The electronic circuitry 402 may include one or more of various electrical circuits, such as: an analog to digital converter("A/D"), a digital to analog converter("D/A"), a power converter, memory, trimming resistors, fuses, programmable links, programmable gates, compensation circuitry, calibration circuitry, biasing circuitry, transistors, transmitters, receivers or signal-processing circuitry. Thousands of sub-micron transistors can be integrated in the external and internal surfaces of the micro-instrument 100. The electronic circuits 402 may also be laminated (e.g. by thin-film deposition) inside of the micro-instrument 100 layers. High density sub-micron memories have been created by Irvine Sensors of Irvine, Calif. for DARPA in that manner.

Detailed Description Text (45):
In one embodiment, a thin-film spiral RF antenna, such as Spiral RF antennas used with radio frequency (RF) communication and identity-tag devices, are formed on or in the interior or exterior of the micro-instrument 100. The antenna receives radiated RF energy to power the electronic circuit 402. The same antenna may be used to transmit and receive signals, including response signals that contain temperature or pressure information.

Detailed Description Text (46):
As the micro-instruments 100 become smaller, the antenna also becomes smaller. Smaller antennas use higher frequencies. Communication frequencies are preferably in the microwave, RF, terahertz, or Gigahertz range.

Detailed Description Text (47):
In one alternative or additional embodiment, the electronic circuit 402 includes an energy source, such as a thin-film battery. The battery preferably includes a multi-laminate interdigitated thin-film cell. Alternatively, electrolytic or galvanic electrodes on the exterior surfaces of the micro-instrument 100 are provided. Such electrodes, when immersed in the blood or other electrolyte, create a slight current by an electrolytic action. In this manner long-lasting power is made available.

Detailed Description Text (48):
Any power source may also provide an offset voltage, calibration voltage, current or other voltage bias to the electronic circuit 402. The electronic circuit 402 uses such voltages, for example, to compensate for unwanted offsets in the pressure or temperature measurements.

Detailed Description Text (53):
Referring to FIG. 5, a section of a living body 510 is shown with a heart 512 and a plurality of micro-instruments 100 in the blood stream and the heart. A probe 500 is placed against the body 510. The ultrasonic imaging probe 500 includes a cable 506, a transmitter 502, and a receiver 504. The transmitter 502 emits an acoustic signal into the body. The receiver 504 receives a response signal from the micro-instruments 100. The transmitter 502 and receiver 504 are the same or different devices, such as an array of piezo-electric elements. The piezo-element(s) may also form the ultrasound imaging array or may be independent from the array. Alternatively, the micro-instrument 100 can generate the response signal without receiving an acoustic signal. That is, the micro-instrument 100 automatically

transmits. In alternative embodiments, the transmitter and receivers are electromagnetic in nature for MRI, CAT scan, PET, optical, x-ray or other imaging.

Detailed Description Text (54):
The probe 500 is coupled with an ultrasound imaging system via cable 506. As shown, transmit and receive beamformers 514 and 516 are coupled with the cable 506. The transmit beamformer 514 comprises any device for generating transmit waveforms, such as the transmit beamformer disclosed in U.S. Pat. No. 5,675,554, the disclosure of which is herein incorporated by reference. The transmit beamformer 514 generates transmit waveforms that are applied to the transmitter 502. In response, the transmitter 502 transmit acoustic energy into the body.

Detailed Description Text (56):
The output of the receive beamformer 516 is electrically connected with a scan converter 518. The scan converter comprises devices for detecting and formatting the data for display as an image. Any of various ultrasound systems may be used, such as the Acuson ultrasound systems with the tradenames 128XP, Aspen or Sequoia, or ultrasound systems made by other manufacturers. In alternative embodiments, the probe 500, transmitter 502, receiver 504, transmit and receive beamformers 514 and 516 and/or scan converter 518 comprise devices for CRT, MRI or CAT scan imaging. The receiver 504 and transmitter 502 are conveniently located in transducer 500, but may be located elsewhere in the system.

Detailed Description Text (59):
The probe 500 acoustically excites the micro-instruments 100 and receives an acoustic response signal. The response signal may include reflected, absorbed or scattered ultrasound energy that is indicative of the induced state of vibration or distortion. The state of vibration in one embodiment is modified by the micro-instrument 100 as a function of the physiological property. Thus, acoustic energy returning from the micro-instruments 100 is used for one or both of acoustic contrast imaging of tissue/blood and/or mapping of a body parameter such as temperature or pressure. In alternative embodiments, other signals from the micro-instrument 100 are used for mapping the body parameter.

Detailed Description Text (61):
In one embodiment, the micro-instrument 100 acts as an acoustically imageable contrast agent. In addition to imaging from echoes reflected from the micro-instrument 100 the signal generated by the micro-instrument 100 representing a physiological parameter is received by the probe 500 and processed to form an diagnostic image conveniently containing both ultrasound tissue and/or blood image information and the mapped parameter (e.g. temp, pres.) information.

Detailed Description Text (62):
For this embodiment, the micro-instrument may also include electrical mechanisms. The micro-instrument 100 transmitter 408 continuously, periodically or responsively transmits parameter information. The continuous transmission mode may be triggered by an initiation signal such as a pulse at a certain frequency. The transmitted information can be frequency modulated or frequency encoded. For example, for a transmitted acoustic signal a shift from 2 MHz to 2.1 MHz may indicate a pressure increase of 1 mm of mercury. This could also be true in the case of a transmitted RF signal.

Detailed Description Text (69):
Other microstructures incorporated into a micro-instrument 100 that goes through either a gradual or threshold change in behavior with temperature or pressure or any other body parameter may be used. The micro-instrument 100 described above utilizes flexural submembers or portions whose acoustic behavior changes with temperature or pressure (the parameter of interest)--and this acoustic change is observed using an insonifying imaging (or other) transducer. We have also described a temperature measurement micro-instrument of the type in FIG. 4 wherein a thermistor or thermocouple communicates via an RF link. Similar pressure or temperature micro-instruments 100 having no flexural parts may be used.

Detailed Description Text (73):
Referring to FIG. 8, one example of a method for using micro-instruments for treatment is shown. The method 900 generates thermal energy in a body to kill cancerous cells and monitors the temperature distribution during that therapy.

Detailed Description Text (76):

At 908 the hyperthermia device (e.g. transducer, microwave horn, RF antenna, etc.) delivers an increment of heat to the tissue. The steps 906 and 908 are repeated until the required thermal dose is delivered at step 910.

Detailed Description Text (77):
The method of FIG. 8 can be used to target organs or cells, such as cancer cells. The cells are destroyed by the thermal energy. The method of FIG. 8 can most beneficially be used in conjunction with volumetric thermal mapping of the body 510.

Detailed Description Text (78):
In one embodiment, the micro-instrument particles are active acoustic transmitters that are synchronized to the receive beamforming of an ultrasound system via a high frequency radio signal transmitted trigger. In this configuration, the ultrasound property mapping subsystem is in receive-only mode. The particles generate ultrasonic energy indicating pressure or temperature, such as by frequency encoding. The ultrasound system generates a property image in response to the energy. Transmission of acoustic energy from the ultrasound system for conventional imaging may be interleaved with reception of energy originally generated from the micro-instruments 100.

Detailed Description Text (79):
A short period of time before the scanner begins receive-beamforming, an RF trigger signal is generated. The micro-instruments 100 upon reception of the trigger signal, latch a pressure or temperature sensed signal and, using a voltage controlled oscillator, resonate an embedded element or cantilever at a frequency that is equivalent to a measured pressure (i.e. low pressure=2 MHz, high pressure=4 MHz). Preferably, a short cycle burst (e.g. 10 cycles) is used. This burst is received and beamformed by the scanner to the proper depth and area within the image plane. The arrangement of FIG. 6 allows the PVDF elements to both sense pressure and acoustically transmit information indicating the pressure value.

Detailed Description Text (80):
In any of the frequency encoded embodiments discussed above, the system applies a short, windowed FFT across the received ultrasound beam broad band signal to encode for center frequency.

Detailed Description Paragraph Table (1):
TABLE 1 Some example Temperature, pressure, ionizing dose, drug parameters that may be concentration, presence of chemical or measured by molecular species (e.g. bacteria, virus, blood micro-instruments sugar protein, genetic constituents) Some example methods External acoustic illumination for providing power to External RF illumination transmit the parameter External microwave or electromagnetic signal from illumination micro-instrument On-board thin-film solid-state battery On-board thin-film electrodes form battery with body fluid Some example methods Changing acoustic behavior of flexural features for sensing parameter Changing electrical signal from a on micro-instruments thermocouple, thermistor, diode, resistor bridge Changing electrical signal from a piezofilm such as PVDF, PZT or ZnO Some example methods Passively, as by analyzing returned, scattered for communicating or reflected illumination energy parameter from Actively, as by RF signal powered by on- micro-instrument board electrochemical battery Semi-actively, as by illumination (to provide power) and subsequent RF transmission Semi-actively, as by acoustic illumination of micro-instrument and generation by that micro-instrument of frequency-encoded pressure information Some example methods Frequency encoding on each micro-instrument- for differentiating such as (a) flexural members which behave as a parameter values function of the physiological parameter, b) an on-board RF or acoustic transmission which is frequency-encoded or digitally encoded.

Other Reference Publication (12):
Jacco A. De Zwart; Fast Magnetic-Resonance Temperature Imaging; Apr. 29, 1996; pp. 86-90.

CLAIMS:

2. The device of claim 1 wherein the observable property comprises a property observable in a modality selected from the group consisting of: ultrasound, magnetic resonance, computerized axial tomography, PET, x-rays and optical imaging.

14. A medical diagnostic ultrasound system for observing a physiological property of

a body, the system comprising:

a transducer operable to transmit energy into the body;

a plurality of micro-instrument particles having an observable property responsive to the ultrasonic energy, the observable property varying as a function of the physiological property of the body; and

a receive beamformer operable to receive signals responsive to the micro-instrument particles along a scan line.

15. The system of claim 14 wherein the transmitted energy comprises ultrasonic energy and the observable property comprises an acoustic response to the ultrasonic energy.

40. A micro-mechanical device for admission into a body and for communicating medical diagnostic information, comprising:

a leadless micro-instrument particle having an observable property that varies as a function of a physiological property, the observable property consisting of a property selected from the group of: harmonic frequency of a signal, amplitude of a plurality of signals, on-off output operation and combinations thereof;

said micro-instrument having a maximum dimension of one millimeter.

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CROSSABEG.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	1
CROSSABLE.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	59
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CROSSAGE.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	2
CROSSALK.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	1
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L20	L19 and (cross$4 with beam$4)	5	L20
L19	L18 and (energ$9)	63	L19
L18	L17 and (power or ratio or SNR)	65	L18
L17	L16 and (beam$4)	66	L17
L16	L14 and (waveguide or wave-guide or "wave guide" or "lamda" or wavelength or wave-length or "wave length" or spher$6 or wavefront or wave-front or "wave front")	142	L16
L15	L14 and (waveguide or wave-guide or "wave guide" or"lamda" or wavelength or wave-length or "wave length" or spher$6 or wavefront or wave-front or "wave front")	141	L15
L14	L13 and (aperature or open$4 or beam$4)	179	L14
L13	L12 and ((parabol$5 or reflect$5 or cassegrain or horn) with (antenna or probe))	206	L13
L12	L11 and (antenna or probe)	2067	L12
L11	L10 and ((single or "multi" or multiple or second or number or multifrequency or another or plurality or group) with frequency)	4278	L11
L10	L1 and (radio or rf or radio-frequency or (radio adj frequency))	24029	L10
L9	L7 and (radio or rf or radio-frequency or (radio adj frequency))	14	L9
L8	L7 and (aperature or open$4 or beam$4)	17	L8
L7	L6 and (spher$6 or wavefront or wave-front or "wave front")	18	L7
L6	L5 and ("lamda" or wavelength or wave-length or "wave length")	34	L6
L5	L4 and (waveguide or wave-guide or "wave guide")	42	L5
L4	L3 and ((parabol$5 or reflect$5 or cassegrain or horn) with (antenna or probe))	219	L4
L3	L2 and (antenna or probe)	2593	L3
L2	L1 and ((single or "multi" or multiple or second or another or plurality or group) with frequency)	6511	L2
L1	((magnetic adj resonance) or MRI or NMR)	146743	L1

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☐ 1. Document ID: US 20020162947 A1

L9: Entry 1 of 14 File: PGPB Nov 7, 2002

PGPUB-DOCUMENT-NUMBER: 20020162947
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020162947 A1

TITLE: Mechanical sensors of electromagnetic fields

PUBLICATION-DATE: November 7, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Weitekamp, Daniel P.	Altadena	CA	US	
Lambert, Bruce	Pasadena	CA	US	

US-CL-CURRENT: 250/214R

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. Desc | Image

☐ 2. Document ID: US 20010051766 A1

L9: Entry 2 of 14 File: PGPB Dec 13, 2001

PGPUB-DOCUMENT-NUMBER: 20010051766
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20010051766 A1

TITLE: Endoscopic smart probe and method

PUBLICATION-DATE: December 13, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Gazdzinski, Robert F.	San Diego	CA	US	

US-CL-CURRENT: 600/309; 128/903, 378/119, 600/300, 600/437, 600/562, 604/65, 606/1, 606/32, 607/92, 623/23.64

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. Desc | Image

☐ 3. Document ID: US 6496736 B1

L9: Entry 3 of 14 File: USPT Dec 17, 2002

US-PAT-NO: 6496736
DOCUMENT-IDENTIFIER: US 6496736 B1

TITLE: Endothelium preserving microwave treatment for atherosclerosis

DATE-ISSUED: December 17, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Carl; James R.	Houston	TX		
Arndt; G. Dickey	Friendswood	TX		
Fink; Patrick W.	Fresno	TX		
Beer; N. Reginald	Houston	TX		
Henry; Phillip D.	Houston	TX		
Pacifico; Antonio	Houston	TX		
Raffoul; George W.	Houston	TX		

US-CL-CURRENT: 607/101; 128/898, 606/33, 606/42, 607/122, 607/156

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC
Draw Desc | Image

☐ 4. Document ID: US 6332087 B1

L9: Entry 4 of 14 File: USPT Dec 18, 2001

US-PAT-NO: 6332087
DOCUMENT-IDENTIFIER: US 6332087 B1

TITLE: Electromagnetic imaging and therapeutic (EMIT) systems

DATE-ISSUED: December 18, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Svenson; Robert H.	Charlotte	NC		
Semenov; Serguei Y.	Moscow			RU
Baranov; Vladimir	Moscow			RU

US-CL-CURRENT: 600/407; 324/637, 600/430

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 5. Document ID: US 6226553 B1

L9: Entry 5 of 14 File: USPT May 1, 2001

US-PAT-NO: 6226553
DOCUMENT-IDENTIFIER: US 6226553 B1

TITLE: Endothelium preserving microwave treatment for atherosclerois

DATE-ISSUED: May 1, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Carl; James R.	Houston	TX		
Arndt; G. Dickey	Friendswood	TX		
Fink; Patrick W.	Fresno	TX		
Beer; N. Reginald	Houston	TX		
Henry; Phillip D.	Houston	TX		
Pacifico; Antonio	Houston	TX		
Raffoul; George W.	Houston	TX		

US-CL-CURRENT: 607/101; 606/33, 607/102, 607/122, 607/154

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 6. Document ID: US 6223086 B1

L9: Entry 6 of 14 File: USPT Apr 24, 2001

US-PAT-NO: 6223086
DOCUMENT-IDENTIFIER: US 6223086 B1

TITLE: Endothelium preserving microwave treatment for atherosclerosis

DATE-ISSUED: April 24, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Carl; James R.	Houston	TX		
Arndt; G. Dickey	Friendswood	TX		
Fink; Patrick W.	Fresno	TX		
Beer; N. Reginald	Houston	TX		
Henry; Phillip D.	Houston	TX		
Pacifico; Antonio	Houston	TX		
Raffoul; George W.	Houston	TX		

US-CL-CURRENT: 607/101; 606/33, 606/41, 607/102, 607/122, 607/154

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 7. Document ID: US 6061589 A

L9: Entry 7 of 14 File: USPT May 9, 2000

US-PAT-NO: 6061589
DOCUMENT-IDENTIFIER: US 6061589 A
** See image for Certificate of Correction **

TITLE: Microwave antenna for cancer detection system

DATE-ISSUED: May 9, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bridges; Jack E.	Park Ridge	IL		
Taflov; Allen	Wilmette	IL		
Hagness; Susan C.	Chicago	IL		
Sahakian; Alan	Northbrook	IL		

US-CL-CURRENT: 600/430

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 8. Document ID: US 6047216 A

L9: Entry 8 of 14 File: USPT Apr 4, 2000

US-PAT-NO: 6047216
DOCUMENT-IDENTIFIER: US 6047216 A

TITLE: Endothelium preserving microwave treatment for atherosclerosis

DATE-ISSUED: April 4, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Carl; James R.	Houston	TX		
Arndt; G. Dickey	Friendswood	TX		
Fink; Patrick W.	Fresno	TX		
Beer; N. Reginald	Houston	TX		
Henry; Phillip D.	Houston	TX		
Pacifico; Antonio	Houston	TX		
Raffoul; George W.	Houston	TX		

US-CL-CURRENT: 607/101; 128/898, 606/33, 606/42, 607/122, 607/156

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 9. Document ID: US 6026173 A

L9: Entry 9 of 14 File: USPT Feb 15, 2000

US-PAT-NO: 6026173
DOCUMENT-IDENTIFIER: US 6026173 A

TITLE: Electromagnetic imaging and therapeutic (EMIT) systems

DATE-ISSUED: February 15, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Svenson; Robert H.	Charlotte	NC	29232	
Semenov; Serguei Y.	Charlotte	NC	29232	
Baranov; Vladimir	Charlotte	NC	29232	

US-CL-CURRENT: 382/131; 324/637, 600/425

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 10. Document ID: US 5829437 A

L9: Entry 10 of 14 File: USPT Nov 3, 1998

US-PAT-NO: 5829437
DOCUMENT-IDENTIFIER: US 5829437 A

TITLE: Microwave method and system to detect and locate cancers in heterogenous tissues

DATE-ISSUED: November 3, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bridges; Jack E.	Park Ridge	IL		

US-CL-CURRENT: 600/430; 324/638, 600/407

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 11. Document ID: US 5807257 A

L9: Entry 11 of 14 File: USPT Sep 15, 1998

US-PAT-NO: 5807257
DOCUMENT-IDENTIFIER: US 5807257 A

TITLE: Breast cancer detection, imaging and screening by electromagnetic millimeter waves

DATE-ISSUED: September 15, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bridges; Jack E.	Park Ridge	IL		

US-CL-CURRENT: 600/430

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 12. Document ID: US 5704355 A

L9: Entry 12 of 14 File: USPT Jan 6, 1998

US-PAT-NO: 5704355
DOCUMENT-IDENTIFIER: US 5704355 A

TITLE: Non-invasive system for breast cancer detection

DATE-ISSUED: January 6, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bridges; Jack E.	Park Ridge	IL	60068	

US-CL-CURRENT: 600/407; 607/101, 607/154

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 13. Document ID: US 5590031 A

L9: Entry 13 of 14 File: USPT Dec 31, 1996

US-PAT-NO: 5590031
DOCUMENT-IDENTIFIER: US 5590031 A

TITLE: System for converting electromagnetic radiation energy to electrical energy

DATE-ISSUED: December 31, 1996

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Mead, Jr.; Franklin B.	Lancaster	CA	93535	
Nachamkin; Jack	Poway	CA	92064	

US-CL-CURRENT: 363/8; 342/6, 363/178

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 14. Document ID: US 5363050 A

L9: Entry 14 of 14 File: USPT Nov 8, 1994

US-PAT-NO: 5363050
DOCUMENT-IDENTIFIER: US 5363050 A
**** See image for Certificate of Correction ****

TITLE: Quantitative dielectric imaging system

DATE-ISSUED: November 8, 1994

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Guo; Wendy W.	Potomac	MD	20854	
Guo; Theodore C.	Potomac	MD	20854	

US-CL-CURRENT: 324/638; 324/642, 324/644, 600/425, 600/429, 702/57, 73/602, 73/620

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Term	Documents
RADIO.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	397619
RADIOS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	12186
RF.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	177290
RFS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	941
RADIO-FREQUENCY.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	14636
RADIO-FREQUENCIES.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	149
RADIO-FREQUENCYS	0
FREQUENCY.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	1370689
FREQUENCIES.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	288887
FREQUENCYS.DWPI,TDBD,EPAB,JPAB,USPT,PGPB.	48
(7 AND ((RADIO-FREQUENCY OR RF OR RADIO) OR (RADIO ADJ FREQUENCY))).USPT,PGPB,JPAB,EPAB,DWPI,TDBD.	14
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Search Results - Record(s) 1 through 63 of 63 returned.

☐ 1. Document ID: US 20030071750 A1

L19: Entry 1 of 63 File: PGPB Apr 17, 2003

PGPUB-DOCUMENT-NUMBER: 20030071750
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030071750 A1

TITLE: High-definition imaging apparatus and method

PUBLICATION-DATE: April 17, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Benitz, Gerald R.	Harvard	MA	US	

US-CL-CURRENT: 342/25; 342/191, 342/194, 342/195

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 2. Document ID: US 20030060711 A1

L19: Entry 2 of 63 File: PGPB Mar 27, 2003

PGPUB-DOCUMENT-NUMBER: 20030060711
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030060711 A1

TITLE: Ultrasound apparatus and method for tissue resonance analysis

PUBLICATION-DATE: March 27, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Michaeli, David	Ashkelon		IL	

US-CL-CURRENT: 600/451

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 3. Document ID: US 20030058502 A1

L19: Entry 3 of 63 File: PGPB Mar 27, 2003

PGPUB-DOCUMENT-NUMBER: 20030058502

PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030058502 A1

TITLE: Communication systems for use with magnetic resonance imaging systems

PUBLICATION-DATE: March 27, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Griffiths, David M.	Pittsburgh	PA	US	
Misic, George J.	Allison Park	PA	US	
Monski, William J.	Sewickley	PA	US	
Ng, Mo Shuen	Pittsburgh	PA	US	

US-CL-CURRENT: 359/152

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 4. Document ID: US 20030023152 A1

L19: Entry 4 of 63 File: PGPB Jan 30, 2003

PGPUB-DOCUMENT-NUMBER: 20030023152
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030023152 A1

TITLE: System for non-invasive measurement of glucose in humans

PUBLICATION-DATE: January 30, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Abbink, Russell E.	Albuquerque	NM	US	
Johnson, Robert D.	Albuquerque	NM	US	
Maynard, John D.	Albuquerque	NM	US	

US-CL-CURRENT: 600/316

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 5. Document ID: US 20030013956 A1

L19: Entry 5 of 63 File: PGPB Jan 16, 2003

PGPUB-DOCUMENT-NUMBER: 20030013956
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20030013956 A1

TITLE: Ultrasound apparatus and method for tissue resonance analysis

PUBLICATION-DATE: January 16, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Michaeli, David	Ashkelon		IL	

US-CL-CURRENT: 600/437

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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6. Document ID: US 20020184235 A1

L19: Entry 6 of 63 File: PGPB Dec 5, 2002

PGPUB-DOCUMENT-NUMBER: 20020184235
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020184235 A1

TITLE: Utility mapping and data distribution system and method

PUBLICATION-DATE: December 5, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Young, Gary	Pella	IA	US	
Alft, Kevin	Pella	IA	US	

US-CL-CURRENT: 707/104.1

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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7. Document ID: US 20020175849 A1

L19: Entry 7 of 63 File: PGPB Nov 28, 2002

PGPUB-DOCUMENT-NUMBER: 20020175849
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020175849 A1

TITLE: Method for locating a concealed object

PUBLICATION-DATE: November 28, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Arndt, G. Dickey	Friendswood	TX	US	
Carl, James R.	Houston	TX	US	
Byerly, Kent A.	Seabrook	TX	US	
Ngo, Phong H.	Friendswood	TX	US	
Stolarczyk, Larry G.	Raton	NM	US	

US-CL-CURRENT: 342/22; 342/192, 342/194, 342/196, 342/27

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 8. Document ID: US 20020162947 A1

L19: Entry 8 of 63 File: PGPB Nov 7, 2002

PGPUB-DOCUMENT-NUMBER: 20020162947
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020162947 A1

TITLE: Mechanical sensors of electromagnetic fields

PUBLICATION-DATE: November 7, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Weitekamp, Daniel P.	Altadena	CA	US	
Lambert, Bruce	Pasadena	CA	US	

US-CL-CURRENT: 250/214R

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 9. Document ID: US 20020159952 A1

L19: Entry 9 of 63 File: PGPB Oct 31, 2002

PGPUB-DOCUMENT-NUMBER: 20020159952
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020159952 A1

TITLE: Novel acoustically active drug delivery systems

PUBLICATION-DATE: October 31, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Unger, Evan C.	Tucson	AZ	US	

US-CL-CURRENT: 424/9.51; 424/9.52

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 10. Document ID: US 20020143357 A1

L19: Entry 10 of 63 File: PGPB Oct 3, 2002

PGPUB-DOCUMENT-NUMBER: 20020143357
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020143357 A1

TITLE: System and method for bracketing and removing tissue

PUBLICATION-DATE: October 3, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Krag, David N.	Shelburne	VT	US	

US-CL-CURRENT: 606/179; 606/151, 606/167

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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11. Document ID: US 20020095087 A1

L19: Entry 11 of 63 File: PGPB Jul 18, 2002

PGPUB-DOCUMENT-NUMBER: 20020095087
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020095087 A1

TITLE: Systems and methods for making noninvasive physiological assessments

PUBLICATION-DATE: July 18, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Mourad, Pierre D.	Seattle	WA	US	
Kliot, Michel	Bellevue	WA	US	
Mesiwala, Ali	Seattle	WA	US	
Patterson, Rex	Kirkland	WA	US	
Jarvik, Jeffrey G.	Seattle	WA	US	

US-CL-CURRENT: 600/442; 600/449

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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12. Document ID: US 20020095075 A1

L19: Entry 12 of 63 File: PGPB Jul 18, 2002

PGPUB-DOCUMENT-NUMBER: 20020095075
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020095075 A1

TITLE: Photonic molecular probe applications

PUBLICATION-DATE: July 18, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Madarasz, Frank	Madison	AL	US	
Krivoshik, David P.	East Amwell Township	NJ	US	

US-CL-CURRENT: 600/310; 356/364, 600/316

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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13. Document ID: US 20020013596 A1

L19: Entry 13 of 63 File: PGPB Jan 31, 2002

PGPUB-DOCUMENT-NUMBER: 20020013596
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20020013596 A1

TITLE: System and method for bracketing and removing tissue

PUBLICATION-DATE: January 31, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Krag, David N.	Shelburne	VT	US	

US-CL-CURRENT: 606/167

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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14. Document ID: US 20010051766 A1

L19: Entry 14 of 63 File: PGPB Dec 13, 2001

PGPUB-DOCUMENT-NUMBER: 20010051766
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20010051766 A1

TITLE: Endoscopic smart probe and method

PUBLICATION-DATE: December 13, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Gazdzinski, Robert F.	San Diego	CA	US	

US-CL-CURRENT: 600/309; 128/903, 378/119, 600/300, 600/437, 600/562, 604/65, 606/1, 606/32, 607/92, 623/23.64

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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15. Document ID: US 20010047137 A1

L19: Entry 15 of 63 File: PGPB Nov 29, 2001

PGPUB-DOCUMENT-NUMBER: 20010047137
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20010047137 A1

TITLE: Methods and apparatus for in vivo identification and characterization of vulnerable atherosclerotic plaques

PUBLICATION-DATE: November 29, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Moreno, Pedro	Lexington	KY	US	
Lodder, Robert A.	Nicholasville	KY	US	
O'Connor, William	Lexington	KY	US	
Muller, James E.	Lexington	KY	US	

US-CL-CURRENT: 600/475; 250/338.1, 250/339.01, 250/339.06, 250/339.11, 600/476, 600/477

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 16. Document ID: US 20010018594 A1

L19: Entry 16 of 63 File: PGPB Aug 30, 2001

PGPUB-DOCUMENT-NUMBER: 20010018594
PGPUB-FILING-TYPE: original-publication-amended
DOCUMENT-IDENTIFIER: US 20010018594 A1

TITLE: System and Method for Bracketing and Removing Tissue

PUBLICATION-DATE: August 30, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Krag , David N.	Shelburne	VT	US	

US-CL-CURRENT: 606/185; 606/167, 606/179

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 17. Document ID: US 6526352 B1

L19: Entry 17 of 63 File: USPT Feb 25, 2003

US-PAT-NO: 6526352
DOCUMENT-IDENTIFIER: US 6526352 B1

TITLE: Method and arrangement for mapping a road

DATE-ISSUED: February 25, 2003

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Breed; David S.	Boonton Township, Morris County	NJ		
Johnson; Wendell C.	Signal Hill	CA		
Castelli; Vittorio	Yorktown Heights	NY		
Seitz; William E.	Bedford	NH		
DuVall; Wilbur E.	Kimberling City	MO		

US-CL-CURRENT: 701/213; 342/357.13, 701/200, 701/208, 701/210

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 18. Document ID: US 6501414 B2

L19: Entry 18 of 63 File: USPT Dec 31, 2002

US-PAT-NO: 6501414
DOCUMENT-IDENTIFIER: US 6501414 B2

TITLE: Method for locating a concealed object

DATE-ISSUED: December 31, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Arndt; G. Dickey	Friendswood	TX		
Carl; James R.	Houston	TX		
Byerly; Kent A.	Seabrook	TX		
Ngo; Phong H.	Friendswood	TX		
Stolarczyk; Larry G.	Raton	NM		

US-CL-CURRENT: 342/22; 342/194, 342/27

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 19. Document ID: US 6496736 B1

L19: Entry 19 of 63 File: USPT Dec 17, 2002

US-PAT-NO: 6496736
DOCUMENT-IDENTIFIER: US 6496736 B1

TITLE: Endothelium preserving microwave treatment for atherosclerosis

DATE-ISSUED: December 17, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Carl; James R.	Houston	TX		
Arndt; G. Dickey	Friendswood	TX		
Fink; Patrick W.	Fresno	TX		
Beer; N. Reginald	Houston	TX		
Henry; Phillip D.	Houston	TX		
Pacifico; Antonio	Houston	TX		
Raffoul; George W.	Houston	TX		

US-CL-CURRENT: 607/101; 128/898, 606/33, 606/42, 607/122, 607/156

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 20. Document ID: US 6454713 B1

L19: Entry 20 of 63 File: USPT Sep 24, 2002

US-PAT-NO: 6454713
DOCUMENT-IDENTIFIER: US 6454713 B1

TITLE: Ultrasound therapeutic apparatus

DATE-ISSUED: September 24, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Ishibashi; Yoshiharu	Tokyo			JP
Fujimoto; Katsuhiko	Urawa			JP
Shibata; Mariko	Yokohama			JP
Suzuki; Takuji	Kawasaki			JP
Aida; Satoshi	Tokyo			JP

US-CL-CURRENT: 600/439

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 21. Document ID: US 6416740 B1

L19: Entry 21 of 63 File: USPT Jul 9, 2002

US-PAT-NO: 6416740
DOCUMENT-IDENTIFIER: US 6416740 B1

TITLE: Acoustically active drug delivery systems

DATE-ISSUED: July 9, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Unger; Evan C.	Tucson	AZ		

US-CL-CURRENT: 424/9.52; 424/450, 424/9.5, 424/9.51

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 22. Document ID: US 6408202 B1

L19: Entry 22 of 63 File: USPT Jun 18, 2002

US-PAT-NO: 6408202
DOCUMENT-IDENTIFIER: US 6408202 B1

TITLE: Transesophageal magnetic resonance analysis method and apparatus

DATE-ISSUED: June 18, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Lima; Joao A. C.	Timonium	MD		
Shunk; Kendrick A.	Baltimore	MD		
Atalar; Ergin	Columbia	MD		

US-CL-CURRENT: 600/423; 324/307, 324/322, 600/380, 600/410, 600/421

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☑ 23. Document ID: US 6368275 B1

L19: Entry 23 of 63 File: USPT Apr 9, 2002

US-PAT-NO: 6368275
DOCUMENT-IDENTIFIER: US 6368275 B1

TITLE: Method and apparatus for diagnostic medical information gathering, hyperthermia treatment, or directed gene therapy

DATE-ISSUED: April 9, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Sliwa; John W.	Los Altos	CA		
Dreschel; William R.	State College	PA		

US-CL-CURRENT: 600/437; 600/302, 600/458, 600/549

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 24. Document ID: US 6363940 B1

L19: Entry 24 of 63 File: USPT Apr 2, 2002

US-PAT-NO: 6363940
DOCUMENT-IDENTIFIER: US 6363940 B1

TITLE: System and method for bracketing and removing tissue

DATE-ISSUED: April 2, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Krag; David N.	Shelburne	VT		

US-CL-CURRENT: 128/899; 600/420, 600/431, 606/184

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw. Desc | Image

☐ 25. Document ID: US 6347251 B1

L19: Entry 25 of 63 File: USPT Feb 12, 2002

US-PAT-NO: 6347251
DOCUMENT-IDENTIFIER: US 6347251 B1

TITLE: Apparatus and method for microwave hyperthermia and acupuncture

DATE-ISSUED: February 12, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Deng; Tianquan	Singapore 600218			SG

US-CL-CURRENT: 607/101; 606/41, 607/102

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 26. Document ID: US 6334846 B1

L19: Entry 26 of 63 File: USPT Jan 1, 2002

US-PAT-NO: 6334846
DOCUMENT-IDENTIFIER: US 6334846 B1
**** See image for Certificate of Correction ****

TITLE: Ultrasound therapeutic apparatus

DATE-ISSUED: January 1, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Ishibashi; Yoshiharu	Tokyo			JP
Fujimoto; Katsuhiko	Urawa			JP
Shibata; Mariko	Yokohama			JP
Suzuki; Takuji	Kawasaki			JP
Aida; Satoshi	Tokyo			JP

US-CL-CURRENT: 600/439; 600/412

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 27. Document ID: US 6332087 B1

L19: Entry 27 of 63 File: USPT Dec 18, 2001

US-PAT-NO: 6332087
DOCUMENT-IDENTIFIER: US 6332087 B1

TITLE: Electromagnetic imaging and therapeutic (EMIT) systems

DATE-ISSUED: December 18, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Svenson; Robert H.	Charlotte	NC		
Semenov; Serguei Y.	Moscow			RU
Baranov; Vladimir	Moscow			RU

US-CL-CURRENT: 600/407; 324/637, 600/430

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 28. Document ID: US 6328694 B1

L19: Entry 28 of 63 File: USPT Dec 11, 2001

US-PAT-NO: 6328694
DOCUMENT-IDENTIFIER: US 6328694 B1

TITLE: Ultrasound apparatus and method for tissue resonance analysis

DATE-ISSUED: December 11, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Michaeli; David	Ashkelon			IL

US-CL-CURRENT: 600/438; 600/451, 600/561

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 29. Document ID: US 6280402 B1

L19: Entry 29 of 63 File: USPT Aug 28, 2001

US-PAT-NO: 6280402
DOCUMENT-IDENTIFIER: US 6280402 B1

TITLE: Ultrasound therapeutic apparatus

DATE-ISSUED: August 28, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Ishibashi; Yoshiharu	Tokyo			JP
Fujimoto; Katsuhiko	Urawa			JP
Shibata; Mariko	Yokohama			JP
Suzuki; Takuji	Kawasaki			JP
Aida; Satoshi	Tokyo			JP

US-CL-CURRENT: 601/2; 600/439

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 30. Document ID: US 6267734 B1

L19: Entry 30 of 63 File: USPT Jul 31, 2001

US-PAT-NO: 6267734
DOCUMENT-IDENTIFIER: US 6267734 B1

TITLE: Ultrasound therapeutic apparatus

DATE-ISSUED: July 31, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Ishibashi; Yoshiharu	Tokyo			JP
Fujimoto; Katsuhiko	Urawa			JP
Shibata; Mariko	Yokohama			JP
Suzuki; Takuji	Kawasaki			JP
Aida; Satoshi	Tokyo			JP

US-CL-CURRENT: 601/2; 600/439

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments KWIC
Draw Desc | Image

☑ 31. Document ID: US 6246895 B1

L19: Entry 31 of 63 File: USPT Jun 12, 2001

US-PAT-NO: 6246895
DOCUMENT-IDENTIFIER: US 6246895 B1

TITLE: Imaging of ultrasonic fields with MRI

DATE-ISSUED: June 12, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Plewes; Donald B.	Toronto			CA

US-CL-CURRENT: 600/410; 324/309

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments KWIC
Draw Desc | Image

☐ 32. Document ID: US 6226553 B1

L19: Entry 32 of 63 File: USPT May 1, 2001

US-PAT-NO: 6226553
DOCUMENT-IDENTIFIER: US 6226553 B1

TITLE: Endothelium preserving microwave treatment for atherosclerois

DATE-ISSUED: May 1, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Carl; James R.	Houston	TX		
Arndt; G. Dickey	Friendswood	TX		
Fink; Patrick W.	Fresno	TX		
Beer; N. Reginald	Houston	TX		
Henry; Phillip D.	Houston	TX		
Pacifico; Antonio	Houston	TX		
Raffoul; George W.	Houston	TX		

US-CL-CURRENT: 607/101; 606/33, 607/102, 607/122, 607/154

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 33. Document ID: US 6223086 B1

L19: Entry 33 of 63 File: USPT Apr 24, 2001

US-PAT-NO: 6223086
DOCUMENT-IDENTIFIER: US 6223086 B1

TITLE: Endothelium preserving microwave treatment for atherosclerosis

DATE-ISSUED: April 24, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Carl; James R.	Houston	TX		
Arndt; G. Dickey	Friendswood	TX		
Fink; Patrick W.	Fresno	TX		
Beer; N. Reginald	Houston	TX		
Henry; Phillip D.	Houston	TX		
Pacifico; Antonio	Houston	TX		
Raffoul; George W.	Houston	TX		

US-CL-CURRENT: 607/101; 606/33, 606/41, 607/102, 607/122, 607/154

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☑ 34. Document ID: US 6221094 B1

L19: Entry 34 of 63 File: USPT Apr 24, 2001

US-PAT-NO: 6221094
DOCUMENT-IDENTIFIER: US 6221094 B1

TITLE: Resonant frequency therapy device

DATE-ISSUED: April 24, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bare; James E.	Albuquerque	NM	87110	

US-CL-CURRENT: 607/1; 607/156, 607/2, 607/88

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☑ 35. Document ID: US 6181131 B1

L19: Entry 35 of 63 File: USPT Jan 30, 2001

US-PAT-NO: 6181131
DOCUMENT-IDENTIFIER: US 6181131 B1
** See image for Certificate of Correction **

TITLE: Magnetic resonance force microscopy with oscillator actuation

DATE-ISSUED: January 30, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bruland; Kelly	Seattle	WA		
Dougherty; William M.	Bothell	WA		
Garbini; Joseph L.	Seattle	WA		
Sidles; John	Seattle	WA		

US-CL-CURRENT: 324/300; 324/307, 324/310, 73/105

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 36. Document ID: US 6086535 A

L19: Entry 36 of 63 File: USPT Jul 11, 2000

US-PAT-NO: 6086535
DOCUMENT-IDENTIFIER: US 6086535 A

TITLE: Ultrasound therapeutic apparataus

DATE-ISSUED: July 11, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Ishibashi; Yoshiharu	Tokyo			JP
Fujimoto; Katsuhiko	Urawa			JP
Shibata; Mariko	Yokohama			JP
Suzuki; Takuji	Kawasaki			JP
Aida; Satoshi	Tokyo			JP

US-CL-CURRENT: 600/439; 601/2

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 37. Document ID: US 6061589 A

L19: Entry 37 of 63 File: USPT May 9, 2000

US-PAT-NO: 6061589
DOCUMENT-IDENTIFIER: US 6061589 A
**** See image for Certificate of Correction ****

TITLE: Microwave antenna for cancer detection system

DATE-ISSUED: May 9, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bridges; Jack E.	Park Ridge	IL		
Taflov; Allen	Wilmette	IL		
Hagness; Susan C.	Chicago	IL		
Sahakian; Alan	Northbrook	IL		

US-CL-CURRENT: 600/430

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 38. Document ID: US 6047216 A

L19: Entry 38 of 63 File: USPT Apr 4, 2000

US-PAT-NO: 6047216
DOCUMENT-IDENTIFIER: US 6047216 A

TITLE: Endothelium preserving microwave treatment for atherosclerosis

DATE-ISSUED: April 4, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Carl; James R.	Houston	TX		
Arndt; G. Dickey	Friendswood	TX		
Fink; Patrick W.	Fresno	TX		
Beer; N. Reginald	Houston	TX		
Henry; Phillip D.	Houston	TX		
Pacifico; Antonio	Houston	TX		
Raffoul; George W.	Houston	TX		

US-CL-CURRENT: 607/101; 128/898, 606/33, 606/42, 607/122, 607/156

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 39. Document ID: US 6026173 A

L19: Entry 39 of 63 File: USPT Feb 15, 2000

US-PAT-NO: 6026173
DOCUMENT-IDENTIFIER: US 6026173 A

TITLE: Electromagnetic imaging and therapeutic (EMIT) systems

DATE-ISSUED: February 15, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Svenson; Robert H.	Charlotte	NC	29232	
Semenov; Serguei Y.	Charlotte	NC	29232	
Baranov; Vladimir	Charlotte	NC	29232	

US-CL-CURRENT: 382/131; 324/637, 600/425

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 40. Document ID: US 6006175 A

L19: Entry 40 of 63 File: USPT Dec 21, 1999

US-PAT-NO: 6006175
DOCUMENT-IDENTIFIER: US 6006175 A

TITLE: Methods and apparatus for non-acoustic speech characterization and recognition

DATE-ISSUED: December 21, 1999

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Holzrichter; John F.	Berkeley	CA		

US-CL-CURRENT: 704/208; 704/205, 704/206, 704/207

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☑ 41. Document ID: US 6005916 A

L19: Entry 41 of 63 File: USPT Dec 21, 1999

US-PAT-NO: 6005916
DOCUMENT-IDENTIFIER: US 6005916 A
** See image for Certificate of Correction **

TITLE: Apparatus and method for imaging with wavefields using inverse scattering techniques

DATE-ISSUED: December 21, 1999

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Johnson; Steven A.	Salt Lake City	UT		
Borup; David T.	Salt Lake City	UT		
Wiskin; James W.	Salt Lake City	UT		
Natterer; Frank	Muenster			DE
Wubeling; F.	Muenster			DE
Zhang; Yongzhi	Madison	WI		
Olsen; Scott Charles	Salt Lake City	UT		

US-CL-CURRENT: 378/87; 378/98, 600/425, 600/437

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw. Desc | Image

☐ 42. Document ID: US 5984881 A

L19: Entry 42 of 63 File: USPT Nov 16, 1999

US-PAT-NO: 5984881
DOCUMENT-IDENTIFIER: US 5984881 A

TITLE: Ultrasound therapeutic apparatus using a therapeutic ultrasonic wave source and an ultrasonic probe

DATE-ISSUED: November 16, 1999

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Ishibashi; Yoshiharu	Tokyo			JP
Fujimoto; Katsuhiko	Urawa			JP
Shibata; Mariko	Yokohama			JP
Suzuki; Takuji	Kawasaki			JP
Aida; Satoshi	Tokyo			JP

US-CL-CURRENT: 601/2

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw. Desc | Image

☐ 43. Document ID: US 5912179 A

L19: Entry 43 of 63 File: USPT Jun 15, 1999

US-PAT-NO: 5912179
DOCUMENT-IDENTIFIER: US 5912179 A

TITLE: Method for determining a level of oxidative stress of a tissue sample

DATE-ISSUED: June 15, 1999

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Alvarez; Juan G.	Boston	MA		
Modell; Mark	Brookline	MA		

US-CL-CURRENT: 436/63; 250/910, 356/301, 436/171, 436/173, 436/64, 436/71, 600/310, 600/323, 600/473, 600/475, 600/476, 600/477, 600/478

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 44. Document ID: US 5835054 A

L19: Entry 44 of 63 File: USPT Nov 10, 1998

US-PAT-NO: 5835054
DOCUMENT-IDENTIFIER: US 5835054 A

TITLE: Ultra wideband ground penetrating radar imaging of heterogeneous solids

DATE-ISSUED: November 10, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Warhus; John P.	Brentwood	CA		
Mast; Jeffrey E.	Livermore	CA		

US-CL-CURRENT: 342/22; 342/179, 342/180, 342/195, 342/196, 342/197

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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☐ 45. Document ID: US 5829437 A

L19: Entry 45 of 63 File: USPT Nov 3, 1998

US-PAT-NO: 5829437
DOCUMENT-IDENTIFIER: US 5829437 A

TITLE: Microwave method and system to detect and locate cancers in heterogenous tissues

DATE-ISSUED: November 3, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bridges; Jack E.	Park Ridge	IL		

US-CL-CURRENT: 600/430; 324/638, 600/407

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 46. Document ID: US 5807257 A

L19: Entry 46 of 63 File: USPT Sep 15, 1998

US-PAT-NO: 5807257
DOCUMENT-IDENTIFIER: US 5807257 A

TITLE: Breast cancer detection, imaging and screening by electromagnetic millimeter waves

DATE-ISSUED: September 15, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bridges; Jack E.	Park Ridge	IL		

US-CL-CURRENT: 600/430

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 47. Document ID: US 5764518 A

L19: Entry 47 of 63 File: USPT Jun 9, 1998

US-PAT-NO: 5764518
DOCUMENT-IDENTIFIER: US 5764518 A

TITLE: Self reproducing fundamental fabricating machine system

DATE-ISSUED: June 9, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Collins; Charles M.	Burke	VA	22015	

US-CL-CURRENT: 700/95; 700/117

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 48. Document ID: US 5751243 A

L19: Entry 48 of 63 File: USPT May 12, 1998

US-PAT-NO: 5751243
DOCUMENT-IDENTIFIER: US 5751243 A

TITLE: Image synthesis using time sequential holography

DATE-ISSUED: May 12, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Turpin; Terry M.	Columbia	MD		

US-CL-CURRENT: 342/179; 250/370.08

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 49. Document ID: US 5736958 A

L19: Entry 49 of 63 File: USPT Apr 7, 1998

US-PAT-NO: 5736958
DOCUMENT-IDENTIFIER: US 5736958 A

TITLE: Image synthesis using time sequential holography

DATE-ISSUED: April 7, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Turpin; Terry M.	Columbia	MD		

US-CL-CURRENT: 342/179; 359/32, 378/87, 600/407, 708/816

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 50. Document ID: US 5729694 A

L19: Entry 50 of 63 File: USPT Mar 17, 1998

US-PAT-NO: 5729694
DOCUMENT-IDENTIFIER: US 5729694 A

TITLE: Speech coding, reconstruction and recognition using acoustics and electromagnetic waves

DATE-ISSUED: March 17, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Holzrichter; John F.	Berkeley	CA		
Ng; Lawrence C.	Danville	CA		

US-CL-CURRENT: 705/17; 704/270, 704/270.1

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 51. Document ID: US 5712165 A

L19: Entry 51 of 63 File: USPT Jan 27, 1998

US-PAT-NO: 5712165
DOCUMENT-IDENTIFIER: US 5712165 A

TITLE: Method and apparatus for detecting hydrocarbon oxidation

DATE-ISSUED: January 27, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Alvarez; Juan G.	Boston	MA		
Modell; Mark	Brookline	MA		

US-CL-CURRENT: 436/21; 250/910, 356/301, 422/82.05, 426/231, 426/87, 436/142, 436/164, 436/172, 436/20, 436/23, 436/60, 436/71

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 52. Document ID: US 5704355 A

L19: Entry 52 of 63 File: USPT Jan 6, 1998

US-PAT-NO: 5704355
DOCUMENT-IDENTIFIER: US 5704355 A

TITLE: Non-invasive system for breast cancer detection

DATE-ISSUED: January 6, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Bridges; Jack E.	Park Ridge	IL	60068	

US-CL-CURRENT: 600/407; 607/101, 607/154

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 53. Document ID: US 5565779 A

L19: Entry 53 of 63 File: USPT Oct 15, 1996

US-PAT-NO: 5565779
DOCUMENT-IDENTIFIER: US 5565779 A

TITLE: MRI front end apparatus and method of operation

DATE-ISSUED: October 15, 1996

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Arakawa; Mitsuaki	Hillsborough	CA		
Chang; Hsu	Fremont	CA		
Van Heteren; John	San Francisco	CA		

US-CL-CURRENT: 324/318; 324/322

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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54. Document ID: US 5483158 A

L19: Entry 54 of 63 File: USPT Jan 9, 1996

US-PAT-NO: 5483158
DOCUMENT-IDENTIFIER: US 5483158 A

TITLE: Method and apparatus for tuning MRI RF coils

DATE-ISSUED: January 9, 1996

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
van Heteren; John	San Francisco	CA		
Arakawa; Mitsuaki	Hillsborough	CA		

US-CL-CURRENT: 324/318; 324/322

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

55. Document ID: US 5461314 A

L19: Entry 55 of 63 File: USPT Oct 24, 1995

US-PAT-NO: 5461314
DOCUMENT-IDENTIFIER: US 5461314 A

TITLE: MRI front end apparatus and method of operation

DATE-ISSUED: October 24, 1995

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Arakawa; Mitsuaki	Hillsborough	CA		
Chang; Hsu	Fremont	CA		
Van Heteren; John	San Francisco	CA		

US-CL-CURRENT: 324/318; 324/322

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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56. Document ID: US 5384573 A

L19: Entry 56 of 63 File: USPT Jan 24, 1995

US-PAT-NO: 5384573
DOCUMENT-IDENTIFIER: US 5384573 A

TITLE: Image synthesis using time sequential holography

DATE-ISSUED: January 24, 1995

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Turpin; Terry M.	Columbia	MD		

US-CL-CURRENT: 342/179; 359/32, 378/87, 600/425, 708/816

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 57. Document ID: US 5381362 A

L19: Entry 57 of 63 File: USPT Jan 10, 1995

US-PAT-NO: 5381362
DOCUMENT-IDENTIFIER: US 5381362 A

TITLE: Reprogrammable matched optical filter and method of using same

DATE-ISSUED: January 10, 1995

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Shen; Xiao An	San Bruno	CA		
Bai; Yu Sheng	Palo Alto	CA		
Pearson; Eric M.	Menlo Park	CA		

US-CL-CURRENT: 708/819; 708/816

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

☐ 58. Document ID: US 5363050 A

L19: Entry 58 of 63 File: USPT Nov 8, 1994

US-PAT-NO: 5363050
DOCUMENT-IDENTIFIER: US 5363050 A
**** See image for Certificate of Correction ****

TITLE: Quantitative dielectric imaging system

DATE-ISSUED: November 8, 1994

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Guo; Wendy W.	Potomac	MD	20854	
Guo; Theodore C.	Potomac	MD	20854	

US-CL-CURRENT: 324/638; 324/642, 324/644, 600/425, 600/429, 702/57, 73/602, 73/620

Full	Title	Citation	Front	Review	Classification	Date	Reference	Sequences	Attachments	KWIC
Draw Desc	Image									

☑ 59. Document ID: US 5227797 A

L19: Entry 59 of 63 File: USPT Jul 13, 1993

US-PAT-NO: 5227797
DOCUMENT-IDENTIFIER: US 5227797 A

TITLE: Radar tomography

DATE-ISSUED: July 13, 1993

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Murphy; Quentin M.	Bronxville	NY	10708	

US-CL-CURRENT: 342/22; 600/425

Full	Title	Citation	Front	Review	Classification	Date	Reference	Sequences	Attachments	KWIC
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☑ 60. Document ID: US 5030956 A

L19: Entry 60 of 63 File: USPT Jul 9, 1991

US-PAT-NO: 5030956
DOCUMENT-IDENTIFIER: US 5030956 A
**** See image for Certificate of Correction ****

TITLE: Radar tomography

DATE-ISSUED: July 9, 1991

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Murphy; Quentin M.	Bronxville	NY	10708	

US-CL-CURRENT: 342/22; 433/25, 600/428, 600/430, 600/590

Full	Title	Citation	Front	Review	Classification	Date	Reference	Sequences	Attachments	KWIC
Draw Desc	Image									

☐ 61. Document ID: US 4945410 A

L19: Entry 61 of 63 File: USPT Jul 31, 1990

US-PAT-NO: 4945410
DOCUMENT-IDENTIFIER: US 4945410 A

TITLE: Satellite communications system for medical related images

DATE-ISSUED: July 31, 1990

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Walling; Paul J.	San Bernardino	CA		

US-CL-CURRENT: 725/67; 358/406, 725/64

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
Draw Desc | Image

62. Document ID: US 4802008 A

L19: Entry 62 of 63 File: USPT Jan 31, 1989

US-PAT-NO: 4802008
DOCUMENT-IDENTIFIER: US 4802008 A

TITLE: Satellite communications system for medical related images

DATE-ISSUED: January 31, 1989

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Walling; Paul J.	San Bernardino	CA	92325	

US-CL-CURRENT: 725/67; 348/22, 358/406, 358/434, 725/63

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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63. Document ID: US 4712560 A

L19: Entry 63 of 63 File: USPT Dec 15, 1987

US-PAT-NO: 4712560
DOCUMENT-IDENTIFIER: US 4712560 A

TITLE: Apparatus and method of acquiring physiological gating signals for magnetic resonance imaging of moving objects

DATE-ISSUED: December 15, 1987

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Schaefer; Daniel J.	Waukesha	WI		
Belt; Kenneth W.	Fort Atkinson	WI		

US-CL-CURRENT: 600/413; 324/309, 600/508, 600/509, 600/534

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | KWIC
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